IMPORTS

In [ ]:
```
import os
import math
import librosa
import librosa.display
import numpy as np
import matplotlib.pyplot as plt
import numpy as np
from sklearn.decomposition import PCA
from sklearn.preprocessing import StandardScaler
from scipy.spatial.distance import cdist
import joblib
import sounddevice as sd
from scipy.signal import butter, lfilter
import soundfile as sf
```

RUTAS Y TIPOS DE FRUTAS

In [ ]:
```
fruit_types      = ['pera', 'banana', 'manzana', 'naranja']
dataset_path     = '../../../dataset/audios/validation'
original_path    = os.path.join(dataset_path, 'original')
processed_path   = os.path.join(dataset_path, 'processed')
model_file       = 'model.pkl'
model            = dict.fromkeys(['pca', 'features', 'scaler'])
```

ORIGINAL TESTS

In [ ]:
```
original = []
original.extend([os.path.join(original_path, filename) for filename in os.
```

PROCESSED TESTS DICT

In [ ]:
```
processed = []
processed.extend([os.path.join(processed_path, filename) for filename in o
```

PARAMETROS DEL AUDIO

In [ ]:
```
FRAME_SIZE = 512# In the documentation says it's convenient for speech.C
HOP_SIZE   = int(FRAME_SIZE/2)
```

FUNCIONES GENERALES DE AUDIO

In [ ]:
```
def load_audio(audiofile):
    test_audio, sr = librosa.load(audiofile, sr = None)
    duration = librosa.get_duration(filename=audiofile, sr=sr)
    return test_audio, sr, duration
```

FILTERS

```
In [ ]: def band_pass_filter(signal, sr, low_cutoff, high_cutoff):
            b, a = butter(N=3, Wn = [low_cutoff, high_cutoff], btype='band', fs=sr
            return lfilter(b, a, signal)
```

PROCCESSING OF THE AUDIO FILES FUNCTIONS

File naming

```
In [ ]: def get_name(original:list):
            return os.path.join(original_path,"validation" + f"{len(original) + 1}
```

Processing

```
In [ ]: def spectral_flux(signal):

            # Calcular el espectrograma de magnitudes
            spectrogram = np.abs(librosa.stft(signal, n_fft = FRAME_SIZE, hop_leng

            # Calcular el flujo espectral
            spectral_flux_values = np.sum(np.diff(spectrogram, axis=1)**2, axis=0)

            return spectral_flux_values
```

```
In [ ]: def process(audio_in, audio_out, rms_umbral = 0.043, flux_umbral = 0.096):
            signal, sr, _ = load_audio(audio_in)

            rms = librosa.feature.rms(y = signal, frame_length = FRAME_SIZE, hop_l
            rms /= np.max(np.abs(rms))
            trms = librosa.times_like(rms, sr = sr, hop_length = HOP_SIZE, n_fft =
            trms /= trms[-1]

            flux = spectral_flux(signal)
            flux /= np.max(np.abs(flux))
            fluxframes = range(len(flux))
            tflux = librosa.frames_to_time(fluxframes, hop_length=HOP_SIZE, n_fft
            tflux /= tflux[-1]

            left_index = np.argmax(np.abs(flux) > flux_umbral)
            rigth_index = len(flux) - 1 - np.argmax(np.abs(np.flip(flux)) > flux_u

            tsignal = librosa.times_like(signal, sr = sr, hop_length=HOP_SIZE, n_f
            tsignal /= tsignal[-1]

            flag       = False
            pad_left   = 0
            pad_rigth  = 0
            flag_left   =  False
            flag_rigth  =  False

            while not flag:
                if rms[0, left_index] > rms_umbral:
```

```
            if left_index > pad_left + 15:
                rms_left = left_index - np.argmax(np.flip(np.abs(rms[0, :l
                if rms_left <= 0:
                    rms_left = left_index
                flag_left = True
            else:
                pad_left += 15
                left_index = pad_left + np.argmax(np.abs(flux[pad_left:])
        else:
                rms_left = left_index
                flag_left = True

        if rms[0, rigth_index] > rms_umbral:
            if rigth_index < (len(flux) - 1 - pad_rigth-15):
                rms_rigth = rigth_index + np.argmax(np.abs(rms[0, rigth_in
                if rms_rigth >= len(flux):
                    rms_rigth = rigth_index
                flag_rigth = True
            else:
                pad_rigth += 15
                rigth_index = len(flux[:-pad_rigth]) - 1 - np.argmax(np.fl
        else:
            rms_rigth = rigth_index
            flag_rigth = True

        flag = flag_left and flag_rigth

    left_index  = min(left_index, rms_left)
    rigth_index = max(rigth_index, rms_rigth)
    mask = tsignal >= tflux[left_index]
    ttrimed = tsignal[mask]
    trimed = signal[mask]
    mask = ttrimed <= tflux[rigth_index]
    ttrimed = ttrimed[mask]
    trimed = trimed[mask]
    sf.write(audio_out, trimed, sr)
```

KNN

In [ ]:

```
def knn(training, test, k_n):
    X            = np.concatenate([v for v in training.values()], axis = 0)
    y            = np.concatenate([[k] * v.shape[0] for k, v in training.it
    dist         = cdist(test, X)
    sorted_ind   = np.argsort(dist, axis = 1)
    sorted_k     = sorted_ind[:, 0:k_n]
    predicted    = []

    for row in sorted_k:
        labels     = list(y[row])
        prediction = max(set(labels), key = labels.count)
        predicted.append(prediction)
    return predicted
```

PLOTTING

In [ ]:
```
#3d
def plot_features3d(features):
    fig = plt.figure()
    ax = fig.add_subplot(111, projection='3d')
    colors = dict(zip(fruit_types,['green','yellow','red','orange']))

    for fruit, points in features.items():
        ax.scatter(points[:, 0], points[:, 1], points[:, 2], c=colors[frui

    ax.set_xlabel('Eje X')
    ax.set_ylabel('Eje Y')
    ax.set_zlabel('Eje Z')
    plt.show()
```

In [ ]:
```
#3d
def plot_features3d_extra(features):
    fig = plt.figure()
    ax = fig.add_subplot(111, projection='3d')
    colors = dict(zip(features.keys(),['green','yellow','red','orange','cy

    for fruit, points in features.items():
        ax.scatter(points[:, 0], points[:, 1], points[:, 2], c=colors[frui
        if fruit == 'validation':
            for i, point in enumerate(points):
                ax.text(point[0], point[1], point[2], f"{i}", color='red',
    ax.set_xlabel('Eje X')
    ax.set_ylabel('Eje Y')
    ax.set_zlabel('Eje Z')
    plt.show()
```

FEATURES EXTRACTION

Features extraction functions

In [ ]:
```
def calculate_split_frequency_bin(split_frequency, sample_rate, num_freque
    """Infer the frequency bin associated to a given split frequency."""

    frequency_range = sample_rate / 2
    frequency_delta_per_bin = frequency_range / num_frequency_bins
    split_frequency_bin = math.floor(split_frequency / frequency_delta_per
    return int(split_frequency_bin)
```

In [ ]:
```
def band_energy_ratio(spectrogram, split_frequency, sample_rate):
    """Calculate band energy ratio with a given split frequency."""

    split_frequency_bin = calculate_split_frequency_bin(split_frequency, s
    band_energy_ratio = []

    # calculate power spectrogram
    power_spectrogram = np.abs(spectrogram) ** 2
```

```
    power_spectrogram = power_spectrogram.T

    # calculate BER value for each frame
    for frame in power_spectrogram:
        sum_power_low_frequencies = frame[:split_frequency_bin].sum()
        sum_power_high_frequencies = frame[split_frequency_bin:].sum()
        band_energy_ratio_current_frame = sum_power_low_frequencies / (sum
        band_energy_ratio.append(band_energy_ratio_current_frame)

    return np.array(band_energy_ratio)
```

In [ ]:
```
def rms(signal, frames, hop):
    return librosa.feature.rms(y=signal, frame_length = frames, hop_length
```

function to get the features

In [ ]:
```
def get_features(signal, sr):
    feature = np.empty((1, 0))

    # BER
    spec = librosa.stft(signal, n_fft = FRAME_SIZE, hop_length = HOP_SIZE)
    # max
    split_frequency = 600
    BER  = band_energy_ratio(spec, split_frequency, sr)
    feat = np.max(np.abs(BER))
    feature = np.append(feature, feat)
    # min
    # 1
    split_frequency = 1900
    BER  = band_energy_ratio(spec, split_frequency, sr)
    feat = np.min(np.abs(BER))
    feature = np.append(feature, feat)
    # 2
    split_frequency = 5000
    BER  = band_energy_ratio(spec, split_frequency, sr)
    feat = np.min(np.abs(BER))
    feature = np.append(feature, feat)
    # 3
    split_frequency = 9000
    BER  = band_energy_ratio(spec, split_frequency, sr)
    feat = np.min(np.abs(BER))
    feature = np.append(feature, feat)
    # std
    # 1
    split_frequency = 8000
    BER  = band_energy_ratio(spec, split_frequency, sr)
    BER /= np.max(np.abs(BER))
    feat = np.std(BER)/np.mean(np.abs(BER))
    feature = np.append(feature, feat)
    # 2
    split_frequency = 1000
    BER  = band_energy_ratio(spec, split_frequency, sr)
    BER /= np.max(np.abs(BER))
```

```
    feat = np.std(BER)/np.mean(np.abs(BER))
    feature = np.append(feature, feat)

    #ZCR
    cutoff = 5000
    cuton = 1000
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    zcr = librosa.feature.zero_crossing_rate(filtered, frame_length=FRAME_
    zcr /= np.max(np.abs(zcr))
    # mean
    feat = np.mean(zcr)
    feature = np.append(feature, feat)
    # maximum
    cutoff = 10000
    cuton = 10
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    zcr = librosa.feature.zero_crossing_rate(filtered, frame_length=FRAME_
    feat = np.max(np.abs(zcr))
    feature = np.append(feature, feat)
    # std
    cutoff = 10000
    cuton  = 20
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    zcr = librosa.feature.zero_crossing_rate(filtered, frame_length=FRAME_
    feat = np.std(zcr)/np.mean(np.abs(zcr))
    feature = np.append(feature, feat)
    # mean local
    cutoff = 5000
    cuton = 1000
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    zcr = librosa.feature.zero_crossing_rate(filtered, frame_length=FRAME_
    zcr /= np.max(np.abs(zcr))
    feat = np.mean(zcr[((len(zcr)*3)//14 - 5) : ((len(zcr)*3)//14 + 5)])
    feature = np.append(feature, feat)
    # local max
    cutoff = 10000
    cuton = 10
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    zcr = librosa.feature.zero_crossing_rate(filtered, frame_length=FRAME_
    feat = np.max(zcr[((len(zcr)*3)//4 - 10) : ((len(zcr)*3)//4 + 10)])
    feature = np.append(feature, feat)

    # Roll off
    cuton = 100
    cutoff = 8500
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    roll_off = librosa.feature.spectral_rolloff(y=filtered, sr=sr, n_fft=F
    roll_off /= np.max(np.abs(roll_off))
    # mean
    feat = np.mean(np.abs(roll_off))
    feature = np.append(feature, feat)
    # max
    cuton = 100
    cutoff = 8500
```

```
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    roll_off = librosa.feature.spectral_rolloff(y=filtered, sr=sr, n_fft=F
    feat = np.max(np.abs(roll_off))
    feature = np.append(feature, feat)
    # std
    cutoff = 8500
    cuton = 50
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    roll_off = librosa.feature.spectral_rolloff(y=filtered, sr=sr, n_fft=F
    roll_off /= np.max(np.abs(roll_off))
    feat = np.std(np.abs(roll_off))/np.mean(np.abs(roll_off))
    feature = np.append(feature, feat)

    #MFCCS
    n_mfcc = 4
    # 1
    cuton = 500
    cutoff = 5000
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    mfccs = librosa.feature.mfcc(y = signal, sr=sr, n_mfcc = n_mfcc, n_fft
    feat = np.max(mfccs, axis = 1)
    feature = np.append(feature, feat[3])

    # 2
    cuton = 10
    cutoff = 8000
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    mfccs = librosa.feature.mfcc(y = filtered, sr=sr, n_mfcc = n_mfcc, n_f
    mfccs /= np.max(np.abs(mfccs), axis = 1, keepdims=True)
    feat = np.std(np.abs(mfccs), axis = 1)/np.mean(np.abs(mfccs), axis = 1
    feature = np.append(feature, feat[3])

    # 3
    cuton = 10
    cutoff = 8000
    filtered = band_pass_filter(signal, sr, cuton, cutoff)
    mfccs = librosa.feature.mfcc(y = filtered, sr=sr, n_mfcc = n_mfcc, n_f
    mfccs /= np.max(np.abs(mfccs), axis = 1, keepdims=True)
    mfccs = mfccs[:, ((mfccs.shape[1]*4) // 5 - 10):((mfccs.shape[1]*4) //
    feat = np.std(np.abs(mfccs), axis=1) / np.mean(np.abs(mfccs), axis=1)
    feature = np.append(feature, feat[1])

    #envelope
    env = rms(signal, FRAME_SIZE, HOP_SIZE)
    env = env.reshape(-1,)
    selected = np.linspace(0, len(env) - 1, 30, dtype=int)
    env = env[selected]
    feat = env[11]
    feature = np.append(feature, feat)
    feat = env[12]
    feature = np.append(feature, feat)

    return feature
```

AUFIO RECORGING

In [ ]:

```
'''duration = 3      # Duración de la grabación en segundos
fs       = 48000  # Frecuencia de muestreo en Hz

print("Grabando...")
data = sd.rec(int(duration * fs), samplerate = fs, channels = 1, dtype = '
sd.wait()
print("Grabación completa.")

file = get_name(original)
sf.write(file, data, fs)
original.append(file)'''
```

Out[ ]:

```
'duration = 3      # Duración de la grabación en segundos\nfs       = 480
00  # Frecuencia de muestreo en Hz\n\nprint("Grabando...")\ndata = sd.rec
(int(duration * fs), samplerate = fs, channels = 1, dtype = \'int16\')\ns
d.wait()\nprint("Grabación completa.")\n\nfile = get_name(original)\nsf.w
rite(file, data, fs)\noriginal.append(file)'
```

PROCESSING

In [ ]:

```
already_processed = [os.path.basename(audio) for audio in processed]
for audio in original:
    basename =  os.path.basename(audio)
    if basename in already_processed:
        pass
    else:
        audio_out = os.path.join(processed_path, basename)
        process(audio, audio_out)
        processed.append(audio_out)
```

FEATURE EXTRACTION

In [ ]:

```
validation_features = None
for audio in processed:
    signal, sr, _ = load_audio(audio)
    feature = get_features(signal, sr)

    if validation_features is not None:
        validation_features = np.vstack([validation_features, feature])
    else:
        validation_features = feature.reshape(1, -1)
```

```
C:\Users\Juan\AppData\Local\Temp\ipykernel_1852\1587896153.py:3: FutureWarn
ing: get_duration() keyword argument 'filename' has been renamed to 'path'
in version 0.10.0.
        This alias will be removed in version 1.0.
  duration = librosa.get_duration(filename=audiofile, sr=sr)
c:\Users\Juan\AppData\Local\Programs\Python\Python311\Lib\site-packages\lib
rosa\feature\spectral.py:2143: UserWarning: Empty filters detected in mel f
requency basis. Some channels will produce empty responses. Try increasing
your sampling rate (and fmax) or reducing n_mels.
  mel_basis = filters.mel(sr=sr, n_fft=n_fft, **kwargs)
```

LOAD THE REDUCED MODEL

In [ ]:

```
model         = joblib.load(model_file)
reduced:dict = model['features']
pca           = model['pca']
scaler        = model['scaler']
```

TRANSFORM

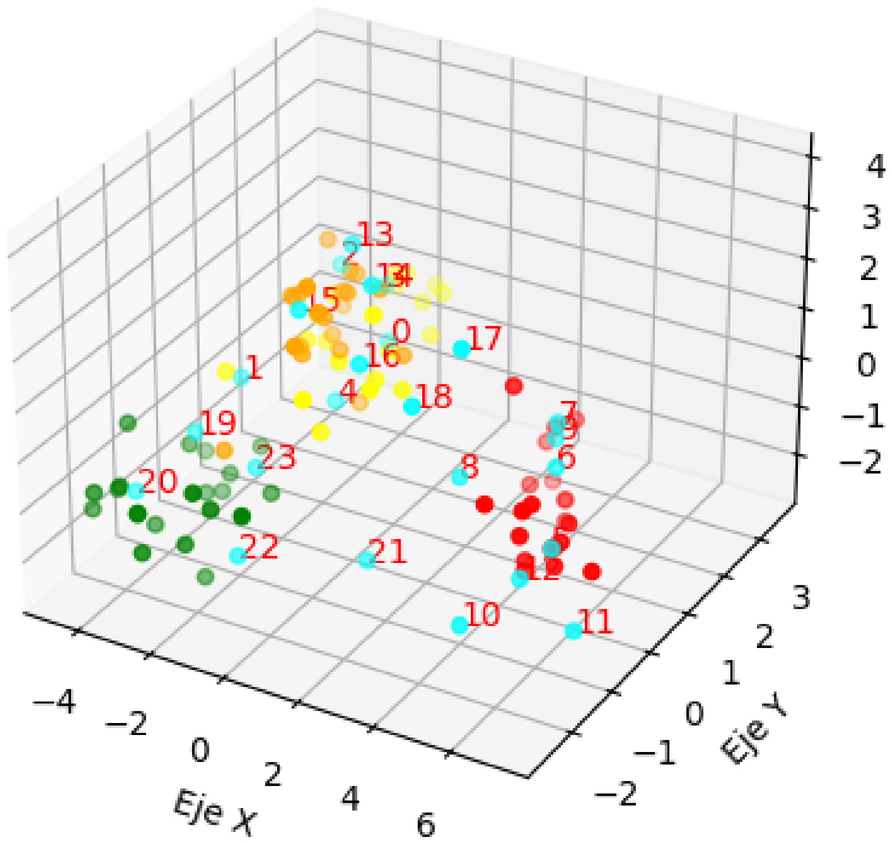
In [ ]:

```
scaled_validation_features = scaler.transform(validation_features)
reduced_validation          = pca.transform(scaled_validation_features)
```

EXTENSION OF THE FEATURES DICT

In [ ]:

```
extra                  = reduced.copy()
extra['validation'] = reduced_validation
plot_features3d_extra(extra)
```



PREDICTION

In [ ]:
```
from prettytable import PrettyTable

prediction  = knn(reduced, reduced_validation, 3)
aciertos    = []
audios      = []
N_aciertos  = 0

for i, audio in enumerate(processed):
    audios.append(os.path.basename(audio))
    if prediction[i] in os.path.basename(audio):
        aciertos.append('acierto')
        N_aciertos += 1
    else:
        aciertos.append('falla')
precission = N_aciertos*100/len(aciertos)

table = PrettyTable()
table.field_names = ['audios'] + audios
table.add_row(['prediction']  + prediction)
table.add_row(['results'] + aciertos)

print(table)
print(f"Se acertaron: {N_aciertos}/{len(prediction)}")
print(f"El porcentaje de aciertos es: {precission}")
```

```
+------------+------------+------------+------------+-----
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
-----+-----------+-----------+-----------+-----------+
|   audios   | banana1.wav | banana2.wav | banana3.wav | banana4.wav | bana
na5.wav | manzana1.wav | manzana2.wav | manzana3.wav | manzana4.wav | manza
na5.wav | manzana6.wav | manzana7.wav | manzana8.wav | naranja1.wav | naran
ja2.wav | naranja3.wav | naranja4.wav | naranja5.wav | naranja6.wav | pera
1.wav | pera2.wav | pera3.wav | pera4.wav | pera5.wav |
+------------+------------+------------+------------+-----
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
-----+-----------+-----------+-----------+-----------+
| prediction |   banana    |   banana    |   banana    |   banana    |   b
anana    |   manzana    |   manzana    |   manzana    |   manzana    |   man
zana    |   manzana    |   manzana    |   manzana    |   naranja    |   nar
anja    |   naranja    |   naranja    |   naranja    |   naranja    |    pe
ra   |    pera   |    pera   |    pera   |    pera   |
|  results   |  acierto   |  acierto   |  acierto   |  acierto   |  ac
ierto    |   acierto    |   acierto    |   acierto    |   acierto    |   aci
erto    |   acierto    |   acierto    |   acierto    |   acierto    |   aci
erto    |   acierto    |   acierto    |   acierto    |   acierto    |  acie
rto  |  acierto  |  acierto  |  acierto  |  acierto  |
+------------+------------+------------+------------+-----
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
--------+-------------+-------------+-------------+------
-----+-----------+-----------+-----------+-----------+
Se acertaron: 24/24
El porcentaje de aciertos es: 100.0
```