Final_Explainability_Visuals

June 29, 2025

0.0.1 Visualizing Spectrogram Similarity with PCA

This part of the analysis transforms spectrogram images of 100 recommended songs into a visual map using **Principal Component Analysis (PCA)**. The goal is to explore how spectrograms relate to each other in terms of shape, structure, and content — allowing us to explain the behavior of the recommender system in visual terms.

Step-by-step explanation:

1. **Load spectrograms**: All `.png` spectrogram images are loaded from the `spectrograms/` folder and converted to grayscale.
2. **Resize and flatten**: Each image is resized (e.g. to 64x64 pixels) and flattened into a one-dimensional vector so it can be treated as a numeric input.
3. **Create image matrix**: These vectors are stacked to form a matrix, where each row is a spectrogram.
4. **Standardization**: The matrix is standardized (zero mean, unit variance) to ensure all pixel features contribute equally to the analysis.
5. **PCA transformation**: PCA reduces the image matrix to just two dimensions (PC1 and PC2), capturing as much variance in the spectrogram structure as possible.
6. **Scatter plot**: Each spectrogram is plotted as a point in 2D space, annotated with its ID. Points that appear close together likely represent similar time–frequency characteristics in the original audio.

This visualization helps us **interpret clusters of audio content**, identify outliers, and understand **how the recommender system may be grouping songs** based on spectrogram similarity.

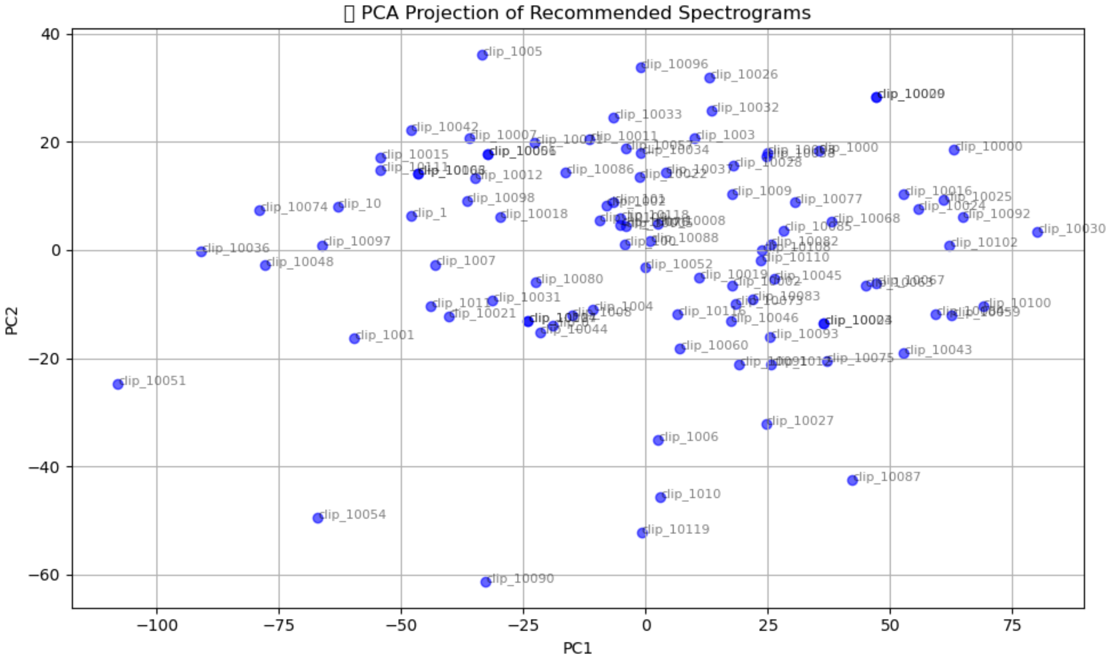
[2]:

```python
import os
import numpy as np
import matplotlib.pyplot as plt
from PIL import Image
from sklearn.decomposition import PCA
from sklearn.manifold import TSNE
from sklearn.preprocessing import StandardScaler

# Path to your 100 spectrograms
spectrogram_dir = "spectrograms"  # or another folder if you've separated␣
 ↪recommended ones
image_files = sorted([f for f in os.listdir(spectrogram_dir) if f.endswith(".
 ↪png")])
```

```
print(f"  Found {len(image_files)} spectrograms")

# Load and flatten images
def load_and_flatten_image(path, size=(64, 64)):
    img = Image.open(path).convert("L")  # grayscale
    img = img.resize(size)
    return np.array(img).flatten()

# Create matrix
image_vectors = []
for fname in image_files:
    full_path = os.path.join(spectrogram_dir, fname)
    vec = load_and_flatten_image(full_path)
    image_vectors.append(vec)

image_vectors = np.array(image_vectors)

# Standardize the data
scaler = StandardScaler()
image_vectors_std = scaler.fit_transform(image_vectors)

# Reduce to 2D
print("  Running PCA...")
pca = PCA(n_components=2)
components = pca.fit_transform(image_vectors_std)

# Visualize
plt.figure(figsize=(10, 6))
plt.scatter(components[:, 0], components[:, 1], c='blue', alpha=0.6)
for i, fname in enumerate(image_files):
    plt.annotate(fname.split(".")[0], (components[i, 0], components[i, 1]), fontsize=8, alpha=0.5)
plt.title("  PCA Projection of Recommended Spectrograms")
plt.xlabel("PC1")
plt.ylabel("PC2")
plt.grid(True)
plt.tight_layout()
plt.show()
```

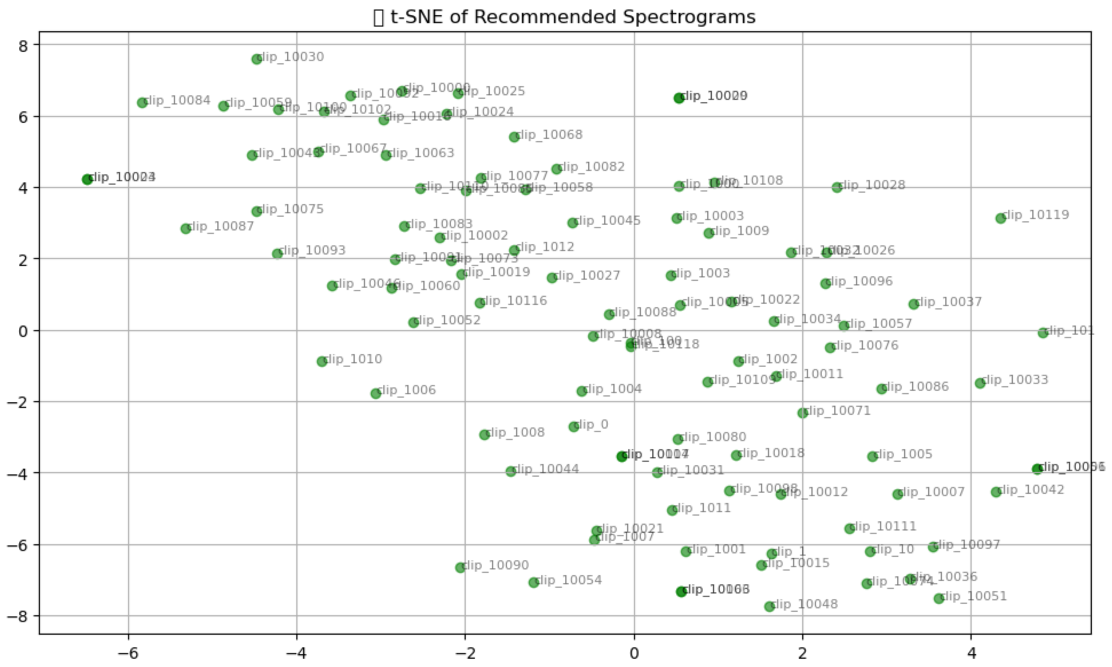
```
 Found 100 spectrograms
 Running PCA…
```

```
/tmp/ipykernel_371/2990119033.py:48: UserWarning: Glyph 127925 (\N{MUSICAL
NOTE}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/opt/conda/lib/python3.12/site-packages/IPython/core/pylabtools.py:170:
UserWarning: Glyph 127925 (\N{MUSICAL NOTE}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



```
[3]: print("  Running t-SNE (this may take 30-60 sec)...")
     tsne = TSNE(n_components=2, perplexity=30, random_state=42)
     components_tsne = tsne.fit_transform(image_vectors_std)

     plt.figure(figsize=(10, 6))
     plt.scatter(components_tsne[:, 0], components_tsne[:, 1], c='green', alpha=0.6)
     for i, fname in enumerate(image_files):
         plt.annotate(fname.split(".")[0], (components_tsne[i, 0],␣
      ↪components_tsne[i, 1]), fontsize=8, alpha=0.5)
     plt.title("  t-SNE of Recommended Spectrograms")
     plt.grid(True)
     plt.tight_layout()
     plt.show()
```

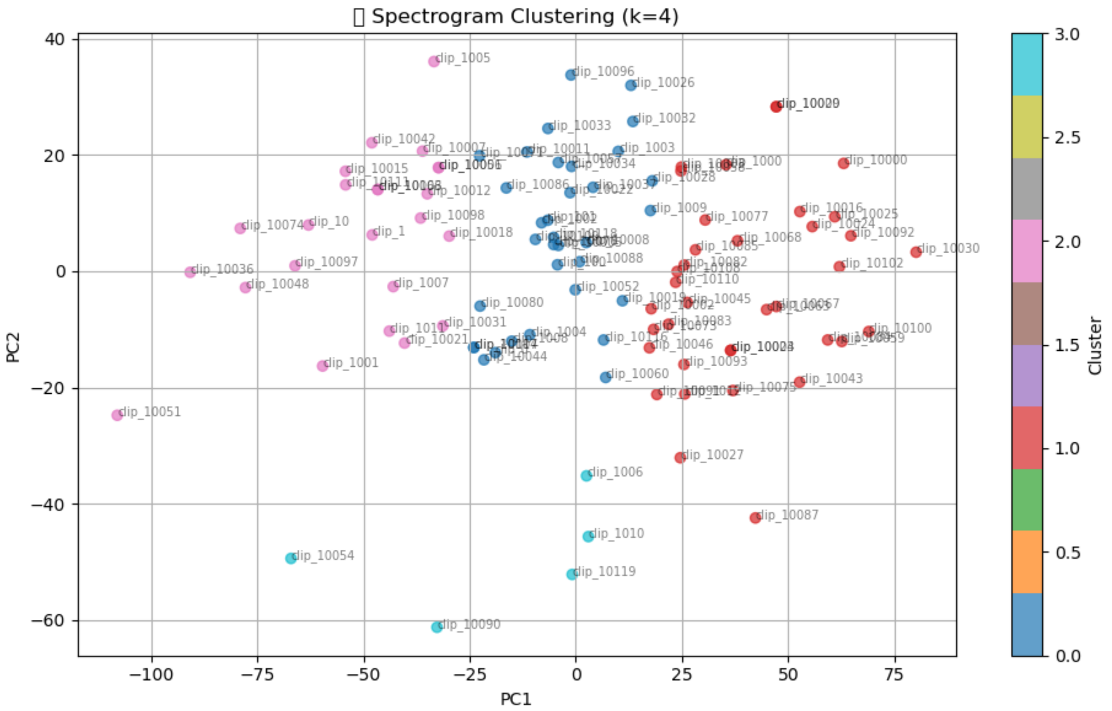
```
 Running t-SNE (this may take 30-60 sec)…

/tmp/ipykernel_371/4198191775.py:11: UserWarning: Glyph 127925 (\N{MUSICAL
NOTE}) missing from font(s) DejaVu Sans.
  plt.tight_layout()
/opt/conda/lib/python3.12/site-packages/IPython/core/pylabtools.py:170:
UserWarning: Glyph 127925 (\N{MUSICAL NOTE}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



[4]:
```python
from sklearn.cluster import KMeans

# Use same data as before (PCA or t-SNE components)
X = components  # ← or use components_tsne if you're working with t-SNE

# Run KMeans (try 3-6 clusters; tune as needed)
n_clusters = 4
kmeans = KMeans(n_clusters=n_clusters, random_state=42)
labels = kmeans.fit_predict(X)

# Plot with cluster coloring
plt.figure(figsize=(10, 6))
scatter = plt.scatter(X[:, 0], X[:, 1], c=labels, cmap='tab10', alpha=0.7)
for i, fname in enumerate(image_files):
    plt.annotate(fname.split(".")[0], (X[i, 0], X[i, 1]), fontsize=7, alpha=0.5)
plt.title(f"  Spectrogram Clustering (k={n_clusters})")
plt.xlabel("PC1" if X is components else "t-SNE 1")
plt.ylabel("PC2" if X is components else "t-SNE 2")
plt.grid(True)
plt.tight_layout()
plt.colorbar(scatter, label="Cluster")
plt.show()
```

```
/tmp/ipykernel_371/374286781.py:20: UserWarning: Glyph 127911 (\N{HEADPHONE})
missing from font(s) DejaVu Sans.
  plt.tight_layout()
```

```
/opt/conda/lib/python3.12/site-packages/IPython/core/pylabtools.py:170:
UserWarning: Glyph 127911 (\N{HEADPHONE}) missing from font(s) DejaVu Sans.
  fig.canvas.print_figure(bytes_io, **kw)
```



```
[5]: import pandas as pd
     import matplotlib.pyplot as plt
     import matplotlib.image as mpimg
     import os

     # Load metadata
     df = pd.read_csv("dataset.csv")

     # Add spectrogram filename column (assumes clip_1.png ... clip_100.png)
     df["spectrogram_path"] = df.index + 1
     df["spectrogram_path"] = df["spectrogram_path"].apply(lambda x: f"spectrograms/
      ↪clip_{x}.png")

     # Show sample
     df.head()
```

```
[5]:    Unnamed: 0                track_id                 artists  \
     0           0  5SuOikwiRyPMVoIQDJUgSV             Gen Hoshino
     1           1  4qPNDBW1i3p13qLCtOKi3A            Ben Woodward
     2           2  1iJBSr7s7jYXzM8EGcbK5b  Ingrid Michaelson;ZAYN
```

```
3           3  6lfxq3CG4xtTiEg7opyCyx             Kina Grannis
4           4  5vjLSffimiIP26QG5WcN2K         Chord Overstreet

                                           album_name  \
0                                              Comedy
1                                    Ghost (Acoustic)
2                                      To Begin Again
3  Crazy Rich Asians (Original Motion Picture Sou…
4                                             Hold On

                   track_name  popularity  duration_ms  explicit  \
0                      Comedy          73       230666     False
1            Ghost - Acoustic          55       149610     False
2              To Begin Again          57       210826     False
3  Can't Help Falling In Love          71       201933     False
4                     Hold On          82       198853     False

   danceability  energy  …  mode  speechiness  acousticness  \
0         0.676  0.4610  …     0       0.1430        0.0322
1         0.420  0.1660  …     1       0.0763        0.9240
2         0.438  0.3590  …     1       0.0557        0.2100
3         0.266  0.0596  …     1       0.0363        0.9050
4         0.618  0.4430  …     1       0.0526        0.4690

   instrumentalness  liveness  valence    tempo  time_signature  track_genre  \
0          0.000001    0.3580    0.715   87.917               4     acoustic
1          0.000006    0.1010    0.267   77.489               4     acoustic
2          0.000000    0.1170    0.120   76.332               4     acoustic
3          0.000071    0.1320    0.143  181.740               3     acoustic
4          0.000000    0.0829    0.167  119.949               4     acoustic

          spectrogram_path
0  spectrograms/clip_1.png
1  spectrograms/clip_2.png
2  spectrograms/clip_3.png
3  spectrograms/clip_4.png
4  spectrograms/clip_5.png

[5 rows x 22 columns]
```

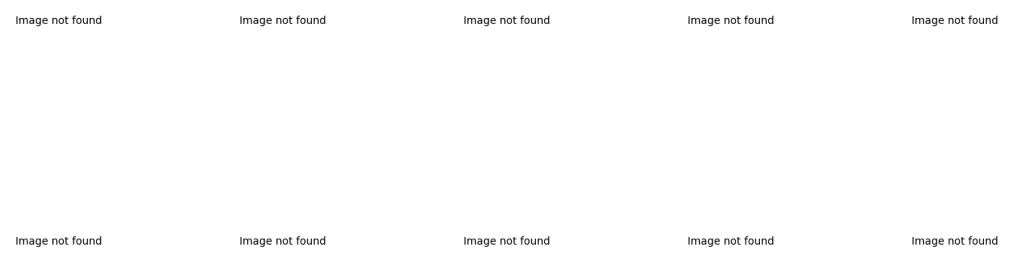
[7]:

```
# Load your dataset
df = pd.read_csv("dataset.csv")

# Assume the first column is the index you want for matching (e.g., 1000, 1001,.
 ↪..)
# and it's the first column in the CSV, with name 'Unnamed: 0' or similar
```

```
df["spectrogram_path"] = df.iloc[:, 0].apply(lambda x: f"spectrograms/clip_{x}.
  ↪png")
```

[8]:

```
import matplotlib.pyplot as plt
import matplotlib.image as mpimg

def show_spectrograms(df, indices):
    plt.figure(figsize=(15, 6))
    for i, idx in enumerate(indices):
        plt.subplot(2, 5, i + 1)
        try:
            img = mpimg.imread(df.loc[idx, "spectrogram_path"])
            plt.imshow(img)
            plt.axis("off")
            plt.title(df.loc[idx, "track_name"], fontsize=8)
        except FileNotFoundError:
            plt.text(0.5, 0.5, "Image not found", ha='center')
            plt.axis("off")
    plt.tight_layout()
    plt.show()

# Show top 10 popular songs
top_indices = df.sort_values("popularity", ascending=False).head(10).index
show_spectrograms(df, top_indices)
```



[11]:

```
import os

files = os.listdir("spectrograms")
print(files[:10])  # sample to see which ID format is used
```

```
['clip_10018.png', 'clip_10030.png', 'clip_10024.png', 'clip_0.png',
'clip_1.png', 'clip_10025.png', 'clip_10031.png', 'clip_10019.png',
    'clip_10027.png', 'clip_10033.png']
```

```
[ ]:
```