

# acoustic\_PCA

January 14, 2025

```
[3]: import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
```

This notebook performs PCA on the set of acoustic features and the scaled feature differences.

First, load the features.

```
[102]: orig_feat = pd.read_csv('../data/processed/expanded/joined_with_features/
↳ all_features_scaled.csv')
```

```
[104]: # grab the acoustic features only
acoustic_feat = orig_feat.iloc[:,1:21]
```

```
[106]: acoustic_feat
```

```
[106]:
```

	rms	spectral_bandwidth	spectral_centroid	spectral_contrast	\
0	-0.341878	0.066554	0.440424	0.506586	
1	-0.434774	-1.315118	-1.049622	0.290653	
2	-0.492169	0.172736	-0.285376	-0.988950	
3	-0.559820	-0.177484	-0.196093	-1.524784	
4	0.090652	-0.837952	-1.337497	1.970131	
..	...	...	...	...	
135	0.185126	-0.118947	0.339915	0.426610	
136	0.348829	-0.637229	-1.384783	-0.149211	
137	-0.548183	1.734812	1.422873	-0.461114	
138	-0.503017	-0.650594	-0.730586	1.634236	
139	-0.447200	-0.991865	-0.915270	2.026114	

	spectral_flatness	spectral_rolloff	zero_crossing_rate	mfccs_offset	\
0	-0.451332	0.348311	0.376068	-0.112493	
1	-0.480526	-1.192311	-0.551984	-0.536671	
2	-0.445185	-0.216417	-0.802337	-0.543731	
3	-0.308431	-0.259075	-0.201213	-0.912058	
4	-0.491282	-1.457028	-1.581369	-1.173415	
..	...	...	...	...	
135	1.652219	0.228797	0.488865	-0.126447	
136	-0.474380	-1.195560	-1.526804	-0.323738	

137	-0.379113	1.486074	1.051931	-0.158671
138	-0.462087	-0.742727	-0.429558	-0.768359
139	-0.491282	-0.991267	-0.528140	-0.429696

	mfcc1	mfcc2	mfcc3	mfcc4	mfcc5	mfcc6	mfcc7	\
0	-0.778928	-1.015857	-0.225135	-0.330494	-0.638302	1.087056	0.617203	
1	0.969615	-0.115785	-1.588444	-0.826390	-2.254977	0.542361	0.485861	
2	-0.006269	0.679399	0.135850	-0.210339	0.151981	1.526968	0.076963	
3	-0.862695	0.459434	-0.645434	1.070612	-0.234536	1.112880	0.882770	
4	0.428365	2.255569	-0.161954	1.440183	1.695354	0.449397	-1.179729	
..	...	...	...	...	...	...	...	
135	-1.586942	0.015508	-1.168933	-0.131453	-0.749538	1.346404	-1.026266	
136	0.813300	2.607361	0.570631	0.982699	-0.512595	0.539046	-0.387748	
137	-0.893742	1.338935	1.328147	-1.306719	0.295250	-1.144739	0.782838	
138	0.555112	0.032074	-0.971100	1.406824	-0.306330	-0.644864	1.568164	
139	1.566300	-0.290227	-0.851044	0.180735	-0.351361	-0.675017	0.457030	

	mfcc8	mfcc9	mfcc10	mfcc11	mfcc12
0	1.456421	0.029930	-0.097627	-0.397106	-0.374183
1	0.833896	-0.633815	-0.933258	-0.018102	0.073077
2	0.006843	-0.047588	0.013357	-0.181287	0.635608
3	0.250759	-0.152036	0.972097	1.063965	0.492936
4	0.455243	-1.272529	2.203114	0.459022	0.152644
..	...	...	...	...	...
135	-0.020775	-0.274373	1.414720	-0.118922	2.127656
136	-1.365056	-0.655223	-1.220662	-0.922210	-0.017725
137	-0.333403	0.556197	0.074172	0.798691	0.345922
138	0.028022	-1.310035	1.988121	0.331271	-0.285788
139	1.271847	-2.368415	0.206971	0.752087	-1.162734

[140 rows x 20 columns]

## 1 PCA: all features

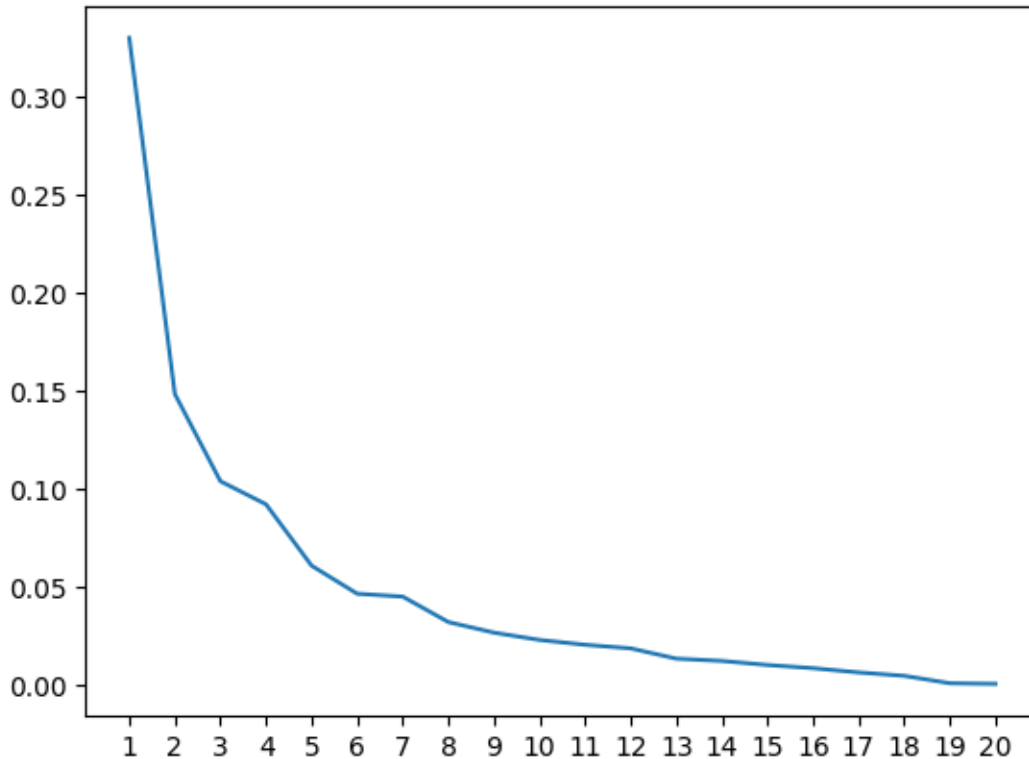
```
[108]: pca = PCA()
```

```
[110]: pca.fit(acoustic_feat)
```

```
[110]: PCA()
```

Visualize explained variance.

```
[112]: plt.plot(range(len(pca.explained_variance_ratio_)), pca.
             ↪ explained_variance_ratio_)
plt.xticks(range(len(pca.explained_variance_ratio_)),
            range(1, len(pca.explained_variance_ratio_)+1));
```



```
[114]: print(pca.explained_variance_ratio_)
```

```
[3.30314164e-01 1.48352958e-01 1.03767708e-01 9.19851025e-02
 6.06407776e-02 4.62850491e-02 4.48109996e-02 3.18145259e-02
 2.64058590e-02 2.26731623e-02 2.02050287e-02 1.83682637e-02
 1.31171139e-02 1.19525921e-02 9.87022726e-03 8.24868444e-03
 6.07217388e-03 4.33844904e-03 5.46481042e-04 2.30679912e-04]
```

Print cumulative sums of explained variance

```
[117]: for i in range(len(pca.explained_variance_ratio_)):
        print("Variance explained by first %d PCs: %f"%(i+1, np.sum(pca.
        ↪ explained_variance_ratio_[:i+1])))
```

```
Variance explained by first 1 PCs: 0.330314
Variance explained by first 2 PCs: 0.478667
Variance explained by first 3 PCs: 0.582435
Variance explained by first 4 PCs: 0.674420
Variance explained by first 5 PCs: 0.735061
Variance explained by first 6 PCs: 0.781346
Variance explained by first 7 PCs: 0.826157
Variance explained by first 8 PCs: 0.857971
Variance explained by first 9 PCs: 0.884377
```

Variance explained by first 10 PCs: 0.907050  
 Variance explained by first 11 PCs: 0.927255  
 Variance explained by first 12 PCs: 0.945624  
 Variance explained by first 13 PCs: 0.958741  
 Variance explained by first 14 PCs: 0.970693  
 Variance explained by first 15 PCs: 0.980564  
 Variance explained by first 16 PCs: 0.988812  
 Variance explained by first 17 PCs: 0.994884  
 Variance explained by first 18 PCs: 0.999223  
 Variance explained by first 19 PCs: 0.999769  
 Variance explained by first 20 PCs: 1.000000

Transform the original data and save.

```
[120]: acoustic PCs = pca.transform(acoustic_feat)
```

```
[122]: pcs_df = pd.DataFrame(acoustic_PCs)
pcs_df.insert(0, 'song_id', orig_feat['song_id'])
```

```
[124]: pcs_df
```

```
[124]:
```

	song_id	0	1	2	\				
0	AChangeIsGonnaCome_SamCooke_Cover5S	0.022937	-0.598798	-0.371011					
1	AChangeIsGonnaCome_SamCooke_Original5S	-2.891199	0.801698	-0.356564					
2	AnotherOneBitesTheDust_Queen_Cover5S	-0.913380	-1.091785	-0.395535					
3	AnotherOneBitesTheDust_Queen_Original5S	-0.794861	-1.910355	-0.635595					
4	BadDay_DanielPowter_Cover5S	-3.152560	-0.288662	1.389626					
..	...	...	...	...					
135	UptownFunk_MarkRonson_Original5S	-0.232629	-0.322775	1.001521					
136	Weak_SWV_Cover5S	-2.388267	1.401820	0.074197					
137	Weak_SWV_Original5S	3.343473	-0.571673	-1.204907					
138	YouLightUpMyLife_DebbyBoone_Cover5S	-1.767656	-0.165546	0.031052					
139	YouLightUpMyLife_DebbyBoone_Original5S	-2.536229	1.136776	0.391491					
		3	4	5	6	7	8	...	\
0		0.781111	0.195429	0.796818	-0.867474	0.459830	-0.492015	...	
1		0.223085	-1.766700	0.254210	-0.920953	-0.823098	-0.367784	...	
2		-0.441324	0.122700	0.161476	1.209218	-1.031817	-0.000057	...	
3		-1.281066	-0.055198	1.522063	-0.247223	-0.635801	0.812591	...	
4		-1.504343	3.230442	-0.824530	-0.913582	-0.867813	-0.423625	...	
..		...	...	...	...	...	...	...	
135		1.230162	0.733727	2.997795	0.367906	-1.185539	-0.971931	...	
136		-1.999824	0.428433	-1.433496	2.149519	-0.790014	0.576768	...	
137		-0.446358	0.817755	-0.287270	0.270217	-1.468730	0.117160	...	
138		-0.536804	0.917327	-0.338145	-2.952617	-0.548051	0.838635	...	
139		0.181811	0.405505	-0.870769	-3.020261	-0.020712	0.358136	...	
		10	11	12	13	14	15	16	\

```

0    0.033540  1.727875  0.501784 -0.549684  0.055635 -0.471566  0.162679
1   -0.486655  0.955277  0.052875 -0.697857  0.191931 -0.150907  0.919135
2   -0.190678  0.708607  0.099601 -0.133101 -0.325815 -0.064960 -0.423612
3   -0.007897  0.026402 -0.315817 -0.299160 -0.691801 -0.291633  0.074297
4    0.216188 -1.203085 -0.131449  0.939943 -0.748131  0.390390 -0.278106
..      ...      ...      ...      ...      ...      ...
135  0.984724 -0.418768 -0.996076 -0.337870 -0.218413 -0.227481  0.121529
136  0.226431 -0.245209 -0.176748 -0.647325 -0.636993  0.018237  0.334956
137 -0.671188 -0.217582 -0.325740  0.422804  0.652490 -0.070668  0.506741
138  0.969405 -0.958001  0.340119 -0.980307 -0.155315  0.411489  0.162836
139 -1.020507 -0.172352  0.841387 -0.085314 -0.347884  0.733405  0.020393

```

```

          17          18          19
0    0.013079  0.014336 -0.038065
1   -0.065129  0.053215  0.010242
2    0.006992 -0.099736 -0.068110
3    0.150395 -0.069100  0.028115
4    0.021525 -0.165151 -0.084024
..      ...      ...      ...
135 -0.306035  0.051720  0.056162
136 -0.263425 -0.039031  0.058868
137 -0.022114 -0.067893 -0.020132
138  0.042291  0.037398  0.132067
139 -0.305660 -0.004176 -0.001018

```

[140 rows x 21 columns]

```
[126]: pcs_df.to_csv('../data/processed/expanded/joined_with_features/acoustic PCs.
        ↪csv', index=False)
```

## 2 PCA on scaled feature differences

```
[5]: scaled_feat_diffs = pd.read_csv('../data/processed/expanded/
        ↪joined_with_features/similarity_and_feature_scaled_differences.csv')
```

```
[9]: scaled_feat_diffs
```

```
[9]:
      song_id  mean_sim  rms_difference \
0  AChangeIsGonnaCome_SamCooke  0.554166   -0.935007
1  AnotherOneBitesTheDust_Queen -0.844765   -0.998811
2      BadDay_DanielPowter  0.312090   -1.117945
3  BetteDavisEyes_KimCarnes  0.351453   -0.483394
4  BlindingLights_TheWeeknd  0.415845    1.612170
..      ...      ...      ...
65  TossinAndTurnin_BobbyLewis -1.140849    0.210475
66  UnbreakMyHeart_ToniBraxton -0.839904    0.611743
67    UptownFunk_MarkRonson  1.742074    0.164616

```

68	Weak_SWV	-0.816959	1.097252
69	YouLightUpMyLife_DebbyBoone	1.922587	-1.028719

	spectral_bandwidth_difference	spectral_centroid_difference	\
0	0.424603	0.506157	
1	-0.861913	-1.148024	
2	-0.624503	-0.705878	
3	-0.072352	-0.695101	
4	0.384503	0.617517	
..	...	...	
65	-0.904161	-1.084117	
66	-0.422557	-0.395587	
67	-0.950916	-0.996790	
68	1.659879	2.062143	
69	-0.873076	-1.035364	

	spectral_contrast_difference	spectral_flatness_difference	\
0	-0.862609	-0.479597	
1	-0.374865	-0.284250	
2	0.405524	-0.504713	
3	0.503072	-0.532619	
4	-0.033445	-0.370761	
..	...	...	
65	0.027523	-0.287040	
66	-0.679705	-0.451690	
67	0.832299	0.391093	
68	-0.716286	-0.359598	
69	-0.594350	-0.479597	

	spectral_rolloff_difference	zero_crossing_rate_difference	\
0	0.600823	-0.171949	
1	-1.185768	-0.561438	
2	-0.763117	0.251408	
3	-0.584231	-0.893569	
4	0.458411	0.520171	
..	...	...	
65	-1.043944	-0.396465	
66	-0.188428	-0.590390	
67	-0.885867	-1.266669	
68	1.961684	1.794613	
69	-0.940217	-1.160147	

	mfccs_offset_difference	...	mfcc11_difference	mfcc12_difference	\
0	-0.564198	...	-0.672166	-0.697801	
1	-0.649801	...	0.165635	-1.075877	
2	1.027642	...	0.520546	-0.993376	
3	-0.113570	...	-0.615367	-0.090300	

4	0.476984	...	-0.272579	-0.955178
..	...	...	...	...
65	-0.385703	...	0.396940	-0.581084
66	-0.583549	...	0.678075	0.045202
67	-0.575489	...	-0.745710	0.198308
68	-0.961336	...	0.625665	-0.801587
69	-0.695267	...	-0.631727	-0.164445

	mfccs_dist	tempo_difference	key_difference	treble_difference	\
0	0.053461	-0.101062	-0.136785	-0.717137	
1	-0.986748	1.667529	-0.136785	-0.717137	
2	1.436681	0.606374	-0.754522	1.374513	
3	-0.404296	-0.384037	-0.754522	-0.717137	
4	-0.617530	-0.596268	-0.754522	-0.717137	
..	...	...	...	...	
65	-1.045328	0.323400	2.334165	-0.717137	
66	-1.058154	3.436120	1.098690	1.374513	
67	-1.094935	-0.808499	-0.754522	-0.717137	
68	0.559681	-0.525524	0.480953	-0.717137	
69	-0.741078	-0.596268	-0.754522	-0.717137	

	tbb_difference	voice_type_difference	mean_valence_difference	\
0	-0.672150	-0.718171	-1.162158	
1	-0.672150	-0.718171	-0.110879	
2	1.466509	1.467567	-0.859291	
3	-0.672150	-0.718171	-0.991589	
4	-0.672150	-0.718171	-0.877836	
..	...	...	...	
65	-0.672150	-0.718171	0.304665	
66	1.466509	1.467567	1.637876	
67	-0.672150	-0.718171	-0.610043	
68	-0.672150	-0.718171	-0.375461	
69	-0.672150	-0.718171	-0.366734	

	mean_arousal_difference
0	1.051598
1	0.899755
2	-0.283486
3	-0.497091
4	-0.082950
..	...
65	-1.058572
66	0.833031
67	-1.106173
68	-0.604696
69	-0.994633

[70 rows x 30 columns]

```
[17]: acoustic_feat_diffs = scaled_feat_diffs.iloc[:,2:22]
acoustic_feat_diffs
# don't include MFCCs distance because that's already a summary of the MFCCs
```

```
[17]:
```

	rms_difference	spectral_bandwidth_difference	\
0	-0.935007	0.424603	
1	-0.998811	-0.861913	
2	-1.117945	-0.624503	
3	-0.483394	-0.072352	
4	1.612170	0.384503	
..	...	...	
65	0.210475	-0.904161	
66	0.611743	-0.422557	
67	0.164616	-0.950916	
68	1.097252	1.659879	
69	-1.028719	-0.873076	

	spectral_centroid_difference	spectral_contrast_difference	\
0	0.506157	-0.862609	
1	-1.148024	-0.374865	
2	-0.705878	0.405524	
3	-0.695101	0.503072	
4	0.617517	-0.033445	
..	...	...	
65	-1.084117	0.027523	
66	-0.395587	-0.679705	
67	-0.996790	0.832299	
68	2.062143	-0.716286	
69	-1.035364	-0.594350	

	spectral_flatness_difference	spectral_rolloff_difference	\
0	-0.479597	0.600823	
1	-0.284250	-1.185768	
2	-0.504713	-0.763117	
3	-0.532619	-0.584231	
4	-0.370761	0.458411	
..	...	...	
65	-0.287040	-1.043944	
66	-0.451690	-0.188428	
67	0.391093	-0.885867	
68	-0.359598	1.961684	
69	-0.479597	-0.940217	

	zero_crossing_rate_difference	mfccs_offset_difference	mfcc1_difference	\
0	-0.171949	-0.564198	0.943430	



1	-0.561438	-0.649801	-0.223937
2	0.251408	1.027642	0.066898
3	-0.893569	-0.113570	0.330067
4	0.520171	0.476984	0.250896
..	...	...	...
65	-0.396465	-0.385703	-1.244793
66	-0.590390	-0.583549	-1.246677
67	-1.266669	-0.575489	-1.120696
68	1.794613	-0.961336	0.889125
69	-1.160147	-0.695267	-0.021426

	mfcc2_difference	mfcc3_difference	mfcc4_difference	mfcc5_difference	\
0	-0.125612	0.381175	-0.792648	0.970694	
1	-0.831154	-0.417782	0.334562	-0.789615	
2	1.979177	0.153676	1.665942	2.695823	
3	0.156865	-0.401805	-1.467522	-0.568214	
4	-0.926032	-1.152439	-1.152338	0.439341	
..	...	...	...	...	
65	-0.476234	-0.048247	-0.734066	-0.326068	
66	-1.030751	-0.655654	0.126229	-0.074347	
67	-0.689092	-1.416031	0.365155	-0.395500	
68	0.256517	-0.450408	1.782553	-0.186711	
69	-0.724992	-1.325462	0.255788	-1.278267	

	mfcc6_difference	mfcc7_difference	mfcc8_difference	mfcc9_difference	\
0	-0.581842	-0.983287	-0.565536	-0.474225	
1	-0.766987	-0.244787	-1.068977	-1.141754	
2	0.744638	-0.755445	-0.954179	-0.463830	
3	-1.027181	-0.141675	-0.487904	-0.515454	
4	0.953000	-0.877507	0.863111	-0.562841	
..	...	...	...	...	
65	-0.477608	-0.519190	0.607264	0.598843	
66	-0.584739	0.887475	-0.252086	-1.112414	
67	0.927327	-0.642599	-0.804383	-1.043626	
68	1.032908	0.154626	-0.021512	0.179435	
69	-1.311245	0.089530	0.260616	-0.003220	

	mfcc10_difference	mfcc11_difference	mfcc12_difference
0	-0.161547	-0.672166	-0.697801
1	0.007680	0.165635	-1.075877
2	3.358993	0.520546	-0.993376
3	0.173161	-0.615367	-0.090300
4	-0.217041	-0.272579	-0.955178
..	...	...	...
65	0.087054	0.396940	-0.581084
66	-0.612336	0.678075	0.045202
67	1.473048	-0.745710	0.198308

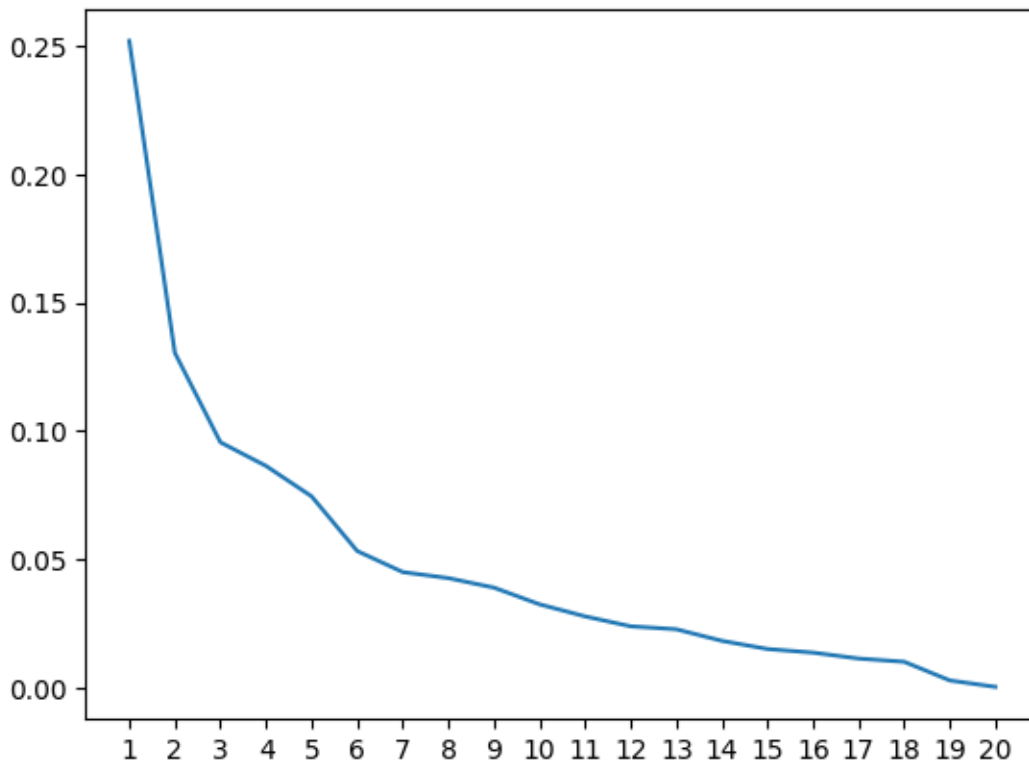
68	0.469681	0.625665	-0.801587
69	1.138178	-0.631727	-0.164445

[70 rows x 20 columns]

```
[21]: pca = PCA()
pca.fit(acoustic_feat_diffs)
```

```
[21]: PCA()
```

```
[23]: plt.plot(range(len(pca.explained_variance_ratio_)), pca.
             ↪ explained_variance_ratio_)
plt.xticks(range(len(pca.explained_variance_ratio_)),
           range(1, len(pca.explained_variance_ratio_)+1));
```



```
[25]: for i in range(len(pca.explained_variance_ratio_)):
       print("Variance explained by first %d PCs: %f"%(i+1, np.sum(pca.
       ↪ explained_variance_ratio_[:i+1])))
```

```
Variance explained by first 1 PCs: 0.251840
Variance explained by first 2 PCs: 0.382331
Variance explained by first 3 PCs: 0.478004
Variance explained by first 4 PCs: 0.564475
```

```

Variance explained by first 5 PCs: 0.639120
Variance explained by first 6 PCs: 0.692495
Variance explained by first 7 PCs: 0.737659
Variance explained by first 8 PCs: 0.780484
Variance explained by first 9 PCs: 0.819606
Variance explained by first 10 PCs: 0.852239
Variance explained by first 11 PCs: 0.880167
Variance explained by first 12 PCs: 0.904239
Variance explained by first 13 PCs: 0.927165
Variance explained by first 14 PCs: 0.945586
Variance explained by first 15 PCs: 0.960831
Variance explained by first 16 PCs: 0.974669
Variance explained by first 17 PCs: 0.986200
Variance explained by first 18 PCs: 0.996472
Variance explained by first 19 PCs: 0.999488
Variance explained by first 20 PCs: 1.000000

```

```
[27]: acoustic_diffs_PCs = pca.transform(acoustic_feat_diffs)
```

```
[29]: pcs_df = pd.DataFrame(acoustic_diffs_PCs)
      pcs_df.insert(0, 'song_id', scaled_feat_diffs['song_id'])
```

```
[31]: pcs_df
```

```
[31]:
```

	song_id	0	1	2	3	\
0	AChangeIsGonnaCome_SamCooke	-0.374017	-2.093954	-0.983404	0.172342	
1	AnotherOneBitesTheDust_Queen	-2.767174	-0.222172	-0.021951	0.219968	
2	BadDay_DanielPowter	0.083418	0.683486	1.049502	-2.687584	
3	BetteDavisEyes_KimCarnes	-1.655406	-0.250530	0.153637	0.212830	
4	BlindingLights_TheWeeknd	0.494351	-0.741291	-0.991394	0.650119	
..	...	...	...	...	...	
65	TossinAndTurnin_BobbyLewis	-1.657682	1.330511	-0.453783	-0.011227	
66	UnbreakMyHeart_ToniBraxton	-1.428879	0.381009	-0.340910	1.321582	
67	UptownFunk_MarkRonson	-2.232949	1.453336	-0.411766	-0.308380	
68	Weak_SWV	3.328566	-1.946731	-0.381569	-0.002573	
69	YouLightUpMyLife_DebbyBoone	-2.353917	0.429639	-0.659606	-0.257131	
		4	5	6	7	8 ... 10 11 \
0		0.229117	0.727443	0.842296	-0.291432	0.131026 ... 0.184890 -0.173028
1		0.673920	-0.697974	-0.130476	-0.713310	0.314995 ... -0.335039 0.569564
2		3.171424	1.838529	1.520556	0.872181	0.569732 ... -0.365611 0.555498
3		-1.378321	-0.141657	0.381310	0.411631	0.251046 ... -0.074047 0.193762
4		-0.141926	0.821419	-1.611815	1.600517	-0.736378 ... -0.577032 0.358192
..		...	...	...	...	...
65		-0.084075	-0.638924	-0.019345	0.239198	-1.161473 ... 0.131338 -0.182919
66		0.514653	-1.018259	0.043578	-0.183472	-0.326499 ... -0.450417 0.599480
67		0.387419	0.618492	-0.857742	1.006386	1.240431 ... -1.420942 0.428414
68		1.934744	-1.082110	-1.249410	0.070914	0.263362 ... -1.174703 -0.004119

```
69 -0.165968 -1.593396 -0.583401 -0.026247 1.026941 ... 0.838128 0.300880
```

```

      12      13      14      15      16      17      18  \
0  0.401422  0.907841  0.414219 -0.082112  0.273074 -0.314486 -0.218664
1  0.269630 -0.375228  0.386080  0.102849  0.746984  0.251434  0.227936
2  0.710201  0.129054 -0.514092  0.171567  0.877684 -1.008613  0.184720
3  0.595595  0.794270  0.248803 -0.354313  0.259602 -0.176120  0.075333
4 -1.276384  0.744934  0.187789  0.148970  0.253568 -0.346319 -0.075830
..      ...      ...      ...      ...      ...      ...
65 -0.248303  0.088448  0.619931  0.213484  0.186987 -0.708639  0.179893
66 -0.911863 -0.066470 -0.909736  0.116486 -0.521595  0.596628 -0.271913
67  0.444618 -0.733999  0.043695  0.305817 -0.719720  0.003388 -0.178033
68 -0.131696 -0.113355 -0.077465 -0.308537 -0.598912 -0.012273  0.127976
69  0.712892 -0.196497 -0.001033  0.051079 -0.052375 -0.680431 -0.346798

```

```

      19
0  0.011600
1  0.046095
2  0.059770
3  0.059403
4 -0.101702
..      ...
65  0.038593
66  0.006634
67  0.010751
68  0.035059
69 -0.035687

```

```
[70 rows x 21 columns]
```

```
[33]: pcs_df.to_csv('../data/processed/expanded/joined_with_features/
↳acoustic_diffs_PCs.csv', index=False)
```