CWRU data classification using machine learning

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Dep : School of Mechanical and Control Engineering

Class : Industrial AI & Automation

Data loading

- Data loading
- Variable declaration
- Data pre - processing to generate each class

```
% clear

addpath('../Assignment_2/Functions');

% user defined function : allFeatures
```

- Each class has different number of datas.
- In needs to be processed since normal class has relatively large number of datas.
- Proper technique for data augmentation : sliding window with overlapping
- # of segements : 20,   Overlap ratio : 0.2

Getting all feature

```
allFeatures();
```

Statisical feature

```
staticFeatures
```

```
staticFeatures = 400×18 table
```

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	mean	std	rms	sra	aav	energy	peak
1 Ball_07_DE_1	0.0153	0.1368	0.1376	0.0938	0.1103	143.3107	0.5204
2 Ball_07_DE_2	0.0150	0.1408	0.1416	0.0953	0.1126	151.6899	0.5258
3 Ball_07_DE_3	0.0150	0.1357	0.1365	0.0924	0.1090	141.0716	0.4754
4 Ball_07_DE_4	0.0148	0.1367	0.1375	0.0932	0.1100	143.0070	0.5580
5 Ball_07_DE_5	0.0142	0.1398	0.1405	0.0951	0.1123	149.4803	0.5671

	mean	std	rms	sra	aav	energy	peak
6 Ball_07_DE_6	0.0135	0.1385	0.1392	0.0939	0.1109	146.5592	0.5921
7 Ball_07_DE_7	0.0135	0.1387	0.1394	0.0949	0.1117	146.9420	0.4756
8 Ball_07_DE_8	0.0130	0.1376	0.1382	0.0938	0.1107	144.5133	0.6070
9 Ball_07_DE_9	0.0123	0.1372	0.1377	0.0934	0.1101	143.5266	0.6070
10 Ball_07_DE_10	0.0122	0.1379	0.1384	0.0926	0.1100	144.9602	0.5495
11 Ball_07_DE_11	0.0120	0.1338	0.1344	0.0915	0.1078	136.6235	0.4699
12 Ball_07_DE_12	0.0119	0.1348	0.1354	0.0919	0.1083	138.6440	0.5791
13 Ball_07_DE_13	0.0117	0.1390	0.1395	0.0944	0.1116	147.1742	0.5105
14 Ball_07_DE_14	0.0114	0.1389	0.1393	0.0941	0.1111	146.8956	0.5161
15 Ball_07_DE_15	0.0111	0.1400	0.1405	0.0957	0.1126	149.2977	0.5391
16 Ball_07_DE_16	0.0111	0.1393	0.1397	0.0957	0.1124	147.7043	0.5313
17 Ball_07_DE_17	0.0112	0.1405	0.1410	0.0947	0.1120	150.4082	0.5659
18 Ball_07_DE_18	0.0114	0.1474	0.1479	0.0996	0.1177	165.4518	0.5583
19 Ball_07_DE_19	0.0111	0.1383	0.1387	0.0935	0.1105	145.6731	0.5191
20 Ball_07_DE_20	0.0101	0.1437	0.1440	0.0964	0.1141	156.5564	0.6039
21 Ball_07_FE_1	0.0148	0.1758	0.1764	0.0967	0.1209	232.8513	1.5764
22 Ball_07_FE_2	0.0142	0.1421	0.1428	0.0859	0.1043	152.5042	1.4608
23 Ball_07_FE_3	0.0139	0.1385	0.1392	0.0862	0.1042	144.9878	1.1076
24 Ball_07_FE_4	0.0137	0.1327	0.1334	0.0824	0.0999	133.0800	1.0447
25 Ball_07_FE_5	0.0135	0.1296	0.1303	0.0823	0.0986	127.0273	1.0447
26 Ball_07_FE_6	0.0133	0.1201	0.1208	0.0765	0.0920	109.2144	0.7106
27 Ball_07_FE_7	0.0132	0.1411	0.1417	0.0834	0.1021	150.2320	1.1065
28 Ball_07_FE_8	0.0129	0.2044	0.2048	0.1051	0.1330	313.6251	2.1985
29 Ball_07_FE_9	0.0127	0.1686	0.1691	0.0901	0.1116	213.8183	2.1985
30 Ball_07_FE_10	0.0125	0.1430	0.1435	0.0856	0.1044	154.1317	1.2805
31 Ball_07_FE_11	0.0123	0.1905	0.1909	0.0978	0.1240	272.5504	1.9882
32 Ball_07_FE_12	0.0122	0.1901	0.1905	0.0947	0.1210	271.4129	1.9882
33 Ball_07_FE_13	0.0121	0.1337	0.1342	0.0810	0.0979	134.7549	1.5086
34 Ball_07_FE_14	0.0119	0.1319	0.1324	0.0802	0.0971	131.1298	1.5086
35 Ball_07_FE_15	0.0117	0.1210	0.1215	0.0784	0.0940	110.4552	0.7369
36 Ball_07_FE_16	0.0118	0.1228	0.1233	0.0801	0.0953	113.8094	1.0647
37 Ball_07_FE_17	0.0119	0.1278	0.1283	0.0769	0.0926	123.1795	1.8321
38 Ball_07_FE_18	0.0117	0.1218	0.1223	0.0806	0.0957	111.9408	1.0014

	mean	std	rms	sra	aav	energy	peak
39 Ball_07_FE_19	0.0113	0.1144	0.1150	0.0762	0.0906	98.8396	0.6080
40 Ball_07_FE_20	0.0111	0.1126	0.1132	0.0745	0.0886	95.6783	0.6418
41 Ball_14_DE_1	0.0050	0.1793	0.1794	0.0960	0.1215	242.0458	1.3422
42 Ball_14_DE_2	0.0050	0.1661	0.1661	0.0892	0.1125	207.5782	1.6979
43 Ball_14_DE_3	0.0051	0.1890	0.1891	0.0946	0.1219	268.9895	1.9700
44 Ball_14_DE_4	0.0050	0.1970	0.1970	0.1000	0.1282	292.0527	1.8368
45 Ball_14_DE_5	0.0049	0.1563	0.1563	0.0840	0.1062	183.8092	1.2040
46 Ball_14_DE_6	0.0050	0.1510	0.1511	0.0800	0.1010	171.6986	1.4782
47 Ball_14_DE_7	0.0050	0.1208	0.1208	0.0634	0.0786	109.8539	1.4782
48 Ball_14_DE_8	0.0051	0.1615	0.1616	0.0813	0.1027	196.4539	2.2611
49 Ball_14_DE_9	0.0049	0.1273	0.1274	0.0658	0.0819	122.1374	2.2611
50 Ball_14_DE_10	0.0046	0.0950	0.0951	0.0603	0.0723	68.0099	0.5762
51 Ball_14_DE_11	0.0045	0.0920	0.0921	0.0571	0.0689	63.8398	0.7342
52 Ball_14_DE_12	0.0042	0.0992	0.0992	0.0608	0.0734	74.0829	1.0990
53 Ball_14_DE_13	0.0040	0.0902	0.0903	0.0590	0.0703	61.3319	0.4763
54 Ball_14_DE_14	0.0041	0.0988	0.0989	0.0627	0.0752	73.6145	0.7961
55 Ball_14_DE_15	0.0045	0.1809	0.1810	0.0862	0.1122	246.3045	2.2782
56 Ball_14_DE_16	0.0045	0.1358	0.1359	0.0737	0.0922	138.8593	1.3697
57 Ball_14_DE_17	0.0046	0.1983	0.1983	0.1027	0.1321	295.8083	1.7714
58 Ball_14_DE_18	0.0046	0.1593	0.1593	0.0915	0.1138	190.9012	1.2498
59 Ball_14_DE_19	0.0048	0.1988	0.1989	0.1029	0.1319	297.5485	2.1960
60 Ball_14_DE_20	0.0046	0.1484	0.1485	0.0825	0.1032	165.4335	1.2688
61 Ball_14_FE_1	0.0064	0.2218	0.2218	0.1186	0.1502	370.9005	2.2089
62 Ball_14_FE_2	0.0063	0.1971	0.1972	0.1139	0.1410	292.9923	1.4573
63 Ball_14_FE_3	0.0064	0.2616	0.2616	0.1382	0.1759	515.9767	2.4134
64 Ball_14_FE_4	0.0062	0.2305	0.2306	0.1269	0.1593	400.7118	2.0044
65 Ball_14_FE_5	0.0064	0.2844	0.2845	0.1400	0.1824	609.9034	2.9467
66 Ball_14_FE_6	0.0062	0.2852	0.2853	0.1426	0.1852	613.3300	2.9467
67 Ball_14_FE_7	0.0061	0.2259	0.2259	0.1292	0.1608	384.7091	1.7532
68 Ball_14_FE_8	0.0062	0.2372	0.2373	0.1190	0.1538	424.2454	1.8723
69 Ball_14_FE_9	0.0063	0.2365	0.2366	0.1074	0.1426	421.7594	2.2825
70 Ball_14_FE_10	0.0066	0.2968	0.2968	0.1470	0.1906	663.9488	3.0812
71 Ball_14_FE_11	0.0063	0.2584	0.2584	0.1157	0.1528	503.3821	3.0812

	mean	std	rms	sra	aav	energy	peak
72 Ball_14_FE_12	0.0061	0.2233	0.2233	0.1097	0.1408	375.9457	2.4394
73 Ball_14_FE_13	0.0062	0.2398	0.2399	0.1168	0.1505	433.7901	2.4394
74 Ball_14_FE_14	0.0064	0.1394	0.1396	0.0873	0.1054	146.8258	0.9406
75 Ball_14_FE_15	0.0060	0.1297	0.1299	0.0827	0.0992	127.1156	0.9955
76 Ball_14_FE_16	0.0057	0.1507	0.1508	0.0903	0.1105	171.4106	1.1565
77 Ball_14_FE_17	0.0057	0.2312	0.2312	0.1128	0.1454	402.9626	2.6292
78 Ball_14_FE_18	0.0057	0.2348	0.2348	0.1256	0.1594	415.5466	1.6105
79 Ball_14_FE_19	0.0055	0.2261	0.2262	0.1185	0.1506	385.6383	2.5032
80 Ball_14_FE_20	0.0054	0.2128	0.2129	0.1089	0.1387	340.5615	2.5983
81 Ball_21_DE_1	0.0212	0.1154	0.1173	0.0771	0.0919	103.6988	0.5838
82 Ball_21_DE_2	0.0027	0.1137	0.1137	0.0740	0.0884	97.3176	0.5838
83 Ball_21_DE_3	-0.0074	0.1170	0.1172	0.0763	0.0912	103.4682	0.5118
84 Ball_21_DE_4	0.0075	0.1174	0.1176	0.0761	0.0911	104.1806	0.5987
85 Ball_21_DE_5	0.0184	0.1258	0.1271	0.0830	0.0990	121.6876	0.5625
86 Ball_21_DE_6	0.0264	0.1248	0.1276	0.0844	0.1002	122.5783	0.5625
87 Ball_21_DE_7	0.0308	0.1320	0.1355	0.0880	0.1052	138.3069	0.9027
88 Ball_21_DE_8	0.0321	0.1423	0.1459	0.0877	0.1064	160.2819	1.2883
89 Ball_21_DE_9	0.0317	0.1749	0.1777	0.0993	0.1236	237.8792	1.5886
90 Ball_21_DE_10	0.0306	0.1534	0.1564	0.0906	0.1116	184.3139	1.6596
91 Ball_21_DE_11	0.0292	0.1476	0.1504	0.0882	0.1081	170.4178	1.6596
92 Ball_21_DE_12	0.0282	0.1182	0.1215	0.0789	0.0943	111.1395	0.5593
93 Ball_21_DE_13	0.0267	0.1272	0.1300	0.0827	0.0995	127.2926	0.8513
94 Ball_21_DE_14	0.0250	0.1972	0.1987	0.1084	0.1361	297.4556	1.6179
95 Ball_21_DE_15	0.0236	0.1440	0.1459	0.0906	0.1099	160.3455	0.8749
96 Ball_21_DE_16	0.0226	0.1531	0.1547	0.0958	0.1164	180.2927	0.8749
97 Ball_21_DE_17	0.0216	0.1172	0.1192	0.0774	0.0927	106.9352	0.5302
98 Ball_21_DE_18	0.0203	0.1182	0.1199	0.0786	0.0937	108.2648	0.5331
99 Ball_21_DE_19	0.0192	0.1157	0.1172	0.0777	0.0922	103.4842	0.5331
100 Ball_21_DE_20	0.0181	0.1150	0.1164	0.0763	0.0908	101.8811	0.5398

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Complex envelop analysis

```
envelopFeatures
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envelopFeatures = 400×37 table
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	BPFO_DE_1st	BPFO_DE_2nd	BPFO_DE_3th	BPFO_DE_4th	BPFO_DE_5th
1 Ball_07_DE_1	0.0120	0.0076	0.0028	0.0018	0.0021
2 Ball_07_DE_2	0.0058	0.0065	0.0024	0.0024	0.0015
3 Ball_07_DE_3	0.0136	0.0062	0.0040	0.0030	0.0014
4 Ball_07_DE_4	0.0122	0.0084	0.0032	0.0028	0.0012
5 Ball_07_DE_5	0.0096	0.0111	0.0030	0.0027	0.0020
6 Ball_07_DE_6	0.0141	0.0142	0.0036	0.0025	0.0021
7 Ball_07_DE_7	0.0139	0.0125	0.0024	0.0026	0.0018
8 Ball_07_DE_8	0.0115	0.0157	0.0033	0.0029	0.0018
9 Ball_07_DE_9	0.0117	0.0107	0.0037	0.0023	0.0015
10 Ball_07_DE_10	0.0190	0.0115	0.0044	0.0031	0.0018
11 Ball_07_DE_11	0.0089	0.0108	0.0037	0.0022	0.0022
12 Ball_07_DE_12	0.0094	0.0120	0.0045	0.0032	0.0018
13 Ball_07_DE_13	0.0104	0.0130	0.0031	0.0040	0.0016
14 Ball_07_DE_14	0.0124	0.0122	0.0038	0.0029	0.0019
15 Ball_07_DE_15	0.0161	0.0125	0.0035	0.0024	0.0015
16 Ball_07_DE_16	0.0191	0.0148	0.0039	0.0033	0.0017
17 Ball_07_DE_17	0.0089	0.0108	0.0029	0.0028	0.0018
18 Ball_07_DE_18	0.0117	0.0163	0.0029	0.0028	0.0021
19 Ball_07_DE_19	0.0155	0.0155	0.0024	0.0028	0.0020
20 Ball_07_DE_20	0.0064	0.0122	0.0025	0.0020	0.0013
21 Ball_07_FE_1	0.0328	0.0028	0.0024	0.0030	0.0021
22 Ball_07_FE_2	0.0058	0.0022	0.0023	0.0022	0.0030
23 Ball_07_FE_3	0.0082	0.0064	0.0038	0.0025	0.0026
24 Ball_07_FE_4	0.0098	0.0098	0.0036	0.0019	0.0026
25 Ball_07_FE_5	0.0083	0.0074	0.0044	0.0025	0.0028
26 Ball_07_FE_6	0.0074	0.0062	0.0020	0.0026	0.0025
27 Ball_07_FE_7	0.0052	0.0044	0.0034	0.0021	0.0028
28 Ball_07_FE_8	0.0061	0.0097	0.0038	0.0035	0.0027
29 Ball_07_FE_9	0.0152	0.0084	0.0030	0.0030	0.0018
30 Ball_07_FE_10	0.0058	0.0077	0.0025	0.0017	0.0021
31 Ball_07_FE_11	0.0096	0.0102	0.0034	0.0027	0.0039
32 Ball_07_FE_12	0.0080	0.0122	0.0031	0.0041	0.0025

	BPFO_DE_1st	BPFO_DE_2nd	BPFO_DE_3th	BPFO_DE_4th	BPFO_DE_5th
33 Ball_07_FE_13	0.0044	0.0084	0.0033	0.0028	0.0022
34 Ball_07_FE_14	0.0103	0.0032	0.0030	0.0016	0.0018
35 Ball_07_FE_15	0.0065	0.0044	0.0017	0.0026	0.0019
36 Ball_07_FE_16	0.0035	0.0036	0.0016	0.0025	0.0021
37 Ball_07_FE_17	0.0100	0.0049	0.0045	0.0014	0.0018
38 Ball_07_FE_18	0.0043	0.0038	0.0029	0.0027	0.0022
39 Ball_07_FE_19	0.0014	0.0022	0.0016	0.0026	0.0015
40 Ball_07_FE_20	0.0075	0.0026	0.0021	0.0021	0.0015
41 Ball_14_DE_1	0.0108	0.0085	0.0041	0.0035	0.0020
42 Ball_14_DE_2	0.0149	0.0062	0.0026	0.0026	0.0018
43 Ball_14_DE_3	0.0113	0.0082	0.0035	0.0037	0.0016
44 Ball_14_DE_4	0.0254	0.0095	0.0032	0.0027	0.0017
45 Ball_14_DE_5	0.0137	0.0029	0.0021	0.0018	0.0018
46 Ball_14_DE_6	0.0087	0.0047	0.0018	0.0020	0.0016
47 Ball_14_DE_7	0.0088	0.0040	0.0025	0.0016	0.0009
48 Ball_14_DE_8	0.0077	0.0064	0.0045	0.0022	0.0017
49 Ball_14_DE_9	0.0049	0.0027	0.0012	0.0018	0.0011
50 Ball_14_DE_10	0.0043	0.0031	0.0011	0.0009	0.0006
51 Ball_14_DE_11	0.0047	0.0026	0.0010	0.0011	0.0007
52 Ball_14_DE_12	0.0076	0.0029	0.0024	0.0016	0.0014
53 Ball_14_DE_13	0.0051	0.0048	0.0016	0.0008	0.0008
54 Ball_14_DE_14	0.0046	0.0013	0.0021	0.0012	0.0008
55 Ball_14_DE_15	0.0121	0.0060	0.0037	0.0013	0.0011
56 Ball_14_DE_16	0.0086	0.0019	0.0022	0.0017	0.0011
57 Ball_14_DE_17	0.0041	0.0056	0.0038	0.0024	0.0023
58 Ball_14_DE_18	0.0075	0.0027	0.0018	0.0015	0.0015
59 Ball_14_DE_19	0.0161	0.0040	0.0016	0.0020	0.0022
60 Ball_14_DE_20	0.0115	0.0034	0.0020	0.0018	0.0012
61 Ball_14_FE_1	0.0190	0.0094	0.0039	0.0057	0.0086
62 Ball_14_FE_2	0.0200	0.0044	0.0045	0.0048	0.0070
63 Ball_14_FE_3	0.0127	0.0074	0.0034	0.0102	0.0114
64 Ball_14_FE_4	0.0136	0.0054	0.0051	0.0065	0.0068
65 Ball_14_FE_5	0.0542	0.0075	0.0059	0.0041	0.0054

	BPFO_DE_1st	BPFO_DE_2nd	BPFO_DE_3th	BPFO_DE_4th	BPFO_DE_5th
66 Ball_14_FE_6	0.0267	0.0040	0.0069	0.0067	0.0088
67 Ball_14_FE_7	0.0174	0.0047	0.0090	0.0046	0.0060
68 Ball_14_FE_8	0.0327	0.0057	0.0053	0.0046	0.0072
69 Ball_14_FE_9	0.0209	0.0080	0.0028	0.0059	0.0049
70 Ball_14_FE_10	0.0457	0.0136	0.0090	0.0072	0.0077
71 Ball_14_FE_11	0.0442	0.0067	0.0067	0.0049	0.0055
72 Ball_14_FE_12	0.0322	0.0093	0.0023	0.0041	0.0053
73 Ball_14_FE_13	0.0312	0.0074	0.0046	0.0039	0.0059
74 Ball_14_FE_14	0.0114	0.0020	0.0036	0.0029	0.0025
75 Ball_14_FE_15	0.0084	0.0037	0.0028	0.0027	0.0024
76 Ball_14_FE_16	0.0145	0.0043	0.0038	0.0025	0.0021
77 Ball_14_FE_17	0.0216	0.0063	0.0023	0.0062	0.0053
78 Ball_14_FE_18	0.0287	0.0112	0.0065	0.0061	0.0058
79 Ball_14_FE_19	0.0225	0.0064	0.0049	0.0054	0.0043
80 Ball_14_FE_20	0.0219	0.0039	0.0066	0.0054	0.0029
81 Ball_21_DE_1	0.0014	0.0049	0.0073	0.0008	0.0010
82 Ball_21_DE_2	0.0039	0.0071	0.0074	0.0011	0.0007
83 Ball_21_DE_3	0.0019	0.0027	0.0080	0.0012	0.0007
84 Ball_21_DE_4	0.0051	0.0014	0.0069	0.0012	0.0008
85 Ball_21_DE_5	0.0076	0.0032	0.0078	0.0008	0.0010
86 Ball_21_DE_6	0.0071	0.0032	0.0060	0.0010	0.0012
87 Ball_21_DE_7	0.0066	0.0065	0.0069	0.0015	0.0012
88 Ball_21_DE_8	0.0103	0.0042	0.0052	0.0015	0.0010
89 Ball_21_DE_9	0.0065	0.0059	0.0066	0.0014	0.0011
90 Ball_21_DE_10	0.0058	0.0041	0.0074	0.0017	0.0011
91 Ball_21_DE_11	0.0065	0.0029	0.0064	0.0013	0.0012
92 Ball_21_DE_12	0.0031	0.0049	0.0071	0.0012	0.0009
93 Ball_21_DE_13	0.0061	0.0033	0.0076	0.0019	0.0010
94 Ball_21_DE_14	0.0066	0.0088	0.0049	0.0023	0.0014
95 Ball_21_DE_15	0.0075	0.0021	0.0073	0.0017	0.0009
96 Ball_21_DE_16	0.0099	0.0038	0.0062	0.0027	0.0016
97 Ball_21_DE_17	0.0054	0.0062	0.0074	0.0009	0.0009
98 Ball_21_DE_18	0.0040	0.0021	0.0077	0.0010	0.0010

	BPFO_DE_1st	BPFO_DE_2nd	BPFO_DE_3th	BPFO_DE_4th	BPFO_DE_5th
99 Ball_21_DE_19	0.0094	0.0035	0.0088	0.0011	0.0006
100 Ball_21_DE_20	0.0052	0.0024	0.0078	0.0013	0.0007

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Wavelet package analysis

```
wavletFeatures
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wavletFeatures = 400×17 table

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	E1	E2	E3	E4	E5	E6	E7
1 Ball_07_DE_1	2.7353	3.9676	1.4652	1.6906	22.8905	10.5841	1.0878
2 Ball_07_DE_2	2.8900	3.9016	1.2789	1.7112	23.8150	8.1665	1.1494
3 Ball_07_DE_3	2.5740	4.3687	1.2789	1.9136	23.4348	8.8605	1.0993
4 Ball_07_DE_4	2.5120	3.3669	1.6251	1.7829	22.3624	8.6028	1.3674
5 Ball_07_DE_5	2.6513	2.8092	1.5770	1.7261	22.5452	8.6830	1.5007
6 Ball_07_DE_6	2.3033	3.3334	1.7418	1.7993	26.5925	8.3230	1.2053
7 Ball_07_DE_7	1.9683	3.1326	1.5860	1.5801	25.1619	9.2976	1.1499
8 Ball_07_DE_8	2.1596	3.9003	1.4306	1.6902	22.1757	8.1996	1.1667
9 Ball_07_DE_9	2.0366	3.6257	1.4085	1.8217	24.2719	8.9817	1.1438
10 Ball_07_DE_10	2.4099	3.5895	1.4108	1.7406	26.4220	8.0497	1.2400
11 Ball_07_DE_11	2.0875	3.0502	1.9121	1.9337	25.5086	7.3704	1.3970
12 Ball_07_DE_12	2.6638	3.2953	1.8345	1.8714	23.9567	8.7730	1.2563
13 Ball_07_DE_13	2.1902	3.0422	1.6038	1.6689	25.0450	8.0933	1.1379
14 Ball_07_DE_14	1.7455	2.9380	1.3759	1.5090	26.0663	9.3451	1.1588
15 Ball_07_DE_15	1.7248	2.8635	1.2734	1.4443	23.2477	9.6228	1.0318
16 Ball_07_DE_16	1.7449	3.0782	1.2826	1.3573	25.3765	9.6926	1.0842
17 Ball_07_DE_17	1.6302	2.8727	1.5756	1.6422	24.9439	8.8420	1.2754
18 Ball_07_DE_18	2.1379	2.1355	1.5384	1.5424	25.8748	7.9874	1.1456
19 Ball_07_DE_19	1.9061	2.9692	1.6486	1.7605	24.7316	9.4835	1.2876
20 Ball_07_DE_20	1.3137	2.9983	1.4151	1.5891	24.6193	9.4778	1.1201
21 Ball_07_FE_1	4.7779	3.1104	0.4848	2.7817	9.9527	14.5365	0.5533
22 Ball_07_FE_2	6.3030	4.6833	1.0654	4.9552	8.9145	10.8563	0.7485
23 Ball_07_FE_3	6.4811	6.3021	1.0650	5.6393	12.3608	12.3907	0.7877
24 Ball_07_FE_4	6.4565	4.5974	0.7450	3.1856	10.1467	12.9474	0.9143
25 Ball_07_FE_5	7.1104	5.0675	0.5639	3.1709	8.3217	13.5959	1.0035

	E1	E2	E3	E4	E5	E6	E7
26 Ball_07_FE_6	7.7084	5.6410	0.6411	3.5674	8.6168	12.3872	0.9392
27 Ball_07_FE_7	5.7765	3.5011	0.6642	3.2339	9.9676	15.6105	0.7867
28 Ball_07_FE_8	3.5398	2.6000	0.4020	2.0131	10.3893	15.6982	0.8484
29 Ball_07_FE_9	4.3944	3.4082	0.2867	1.8341	8.4344	14.9117	0.9003
30 Ball_07_FE_10	5.9868	4.3080	0.8255	3.6883	8.1568	10.4337	0.7563
31 Ball_07_FE_11	3.8489	3.0325	0.7194	3.0243	12.4480	12.7615	1.2827
32 Ball_07_FE_12	3.1223	2.6496	0.5466	2.2193	13.1493	12.6061	1.3097
33 Ball_07_FE_13	7.1782	4.2652	0.5770	2.9356	9.8099	11.0462	0.8191
34 Ball_07_FE_14	7.0393	4.5177	0.5942	3.0941	8.5640	11.6816	0.8781
35 Ball_07_FE_15	6.9705	5.5042	0.8089	4.6627	8.1425	12.2355	1.4053
36 Ball_07_FE_16	9.7650	7.4120	1.3415	5.2472	7.5820	10.9496	1.6565
37 Ball_07_FE_17	8.1910	4.2513	0.5016	2.8887	7.0909	13.0237	0.7257
38 Ball_07_FE_18	8.0573	5.6087	1.0115	4.7625	8.3384	9.9793	0.8027
39 Ball_07_FE_19	10.2761	6.2214	1.4859	6.4684	7.9613	9.7548	0.9477
40 Ball_07_FE_20	9.7098	4.9578	0.9533	5.0052	8.9593	11.6956	0.9783
41 Ball_14_DE_1	2.1031	5.7074	1.6390	1.6465	32.3154	6.2955	1.4057
42 Ball_14_DE_2	2.1914	5.0827	2.0127	1.7914	25.1430	7.3193	1.4662
43 Ball_14_DE_3	1.6228	4.3444	1.4994	1.2782	35.7322	6.1653	1.2904
44 Ball_14_DE_4	1.4070	2.9611	1.4173	1.0245	31.4881	5.6812	1.1228
45 Ball_14_DE_5	2.0479	5.1868	2.7893	1.8717	27.2833	5.5945	1.8755
46 Ball_14_DE_6	2.4040	4.9695	2.6433	1.5856	30.4739	8.8145	1.9534
47 Ball_14_DE_7	3.3990	9.1651	4.0771	2.9116	31.1869	9.9301	2.8786
48 Ball_14_DE_8	3.1205	10.3422	2.1336	2.8740	27.3738	3.8707	1.8031
49 Ball_14_DE_9	3.1971	9.7071	3.1627	3.2080	20.1271	3.4377	2.3881
50 Ball_14_DE_10	4.7104	11.8733	5.3381	4.3159	23.0715	5.2510	3.9653
51 Ball_14_DE_11	4.0822	8.8074	5.8770	3.7747	22.4967	5.7544	4.1172
52 Ball_14_DE_12	4.3523	7.8923	5.7991	3.7626	23.9293	4.9165	4.2588
53 Ball_14_DE_13	4.8659	11.2418	7.2720	4.4269	20.2106	4.8842	5.2517
54 Ball_14_DE_14	4.1358	16.2467	5.7192	5.3421	21.4197	5.8065	3.9651
55 Ball_14_DE_15	2.9057	10.8653	2.1998	2.9364	25.8138	8.2263	1.6238
56 Ball_14_DE_16	4.7409	8.6412	2.6508	3.1761	32.6219	5.1019	2.0143
57 Ball_14_DE_17	1.8083	5.6163	1.4688	1.6948	31.8736	7.7754	1.0749
58 Ball_14_DE_18	2.0878	5.0933	2.1320	1.9922	29.1383	7.1253	1.5625

	E1	E2	E3	E4	E5	E6	E7
59 Ball_14_DE_19	2.0828	5.3478	1.5866	1.6188	23.8656	6.0145	1.1837
60 Ball_14_DE_20	1.9985	6.8206	3.0110	2.3665	29.6850	5.1230	2.4086
61 Ball_14_FE_1	1.2953	1.9332	0.3048	2.4897	9.4115	10.6288	0.9277
62 Ball_14_FE_2	1.7600	2.2900	0.3314	2.7581	7.0929	8.8558	0.8863
63 Ball_14_FE_3	1.4879	1.3705	0.3147	1.7156	7.6684	9.9577	0.8459
64 Ball_14_FE_4	1.3598	1.6146	0.6272	2.0652	4.8898	9.5729	1.1824
65 Ball_14_FE_5	0.9105	1.3202	0.4324	1.9773	6.3574	7.5445	1.5196
66 Ball_14_FE_6	0.8587	1.5065	0.7487	2.4190	10.0371	9.4552	1.5512
67 Ball_14_FE_7	1.2939	2.0986	0.3461	2.3341	7.6552	11.1473	0.9344
68 Ball_14_FE_8	1.2451	2.0623	0.3008	2.6897	9.3897	9.5141	0.8632
69 Ball_14_FE_9	1.4767	2.0261	0.4132	3.1504	6.4491	14.8200	0.9576
70 Ball_14_FE_10	0.7913	1.5556	0.2862	1.9904	6.9287	11.9347	0.8158
71 Ball_14_FE_11	1.0460	1.6334	0.3860	2.4312	8.7144	7.2840	0.8418
72 Ball_14_FE_12	1.5040	1.9775	0.5081	3.0093	4.2272	7.3938	0.7610
73 Ball_14_FE_13	1.4296	1.6635	0.4187	1.9757	5.0389	7.0850	0.7598
74 Ball_14_FE_14	3.5015	3.9300	0.7718	5.2979	3.3718	5.1049	1.7652
75 Ball_14_FE_15	3.4767	5.4387	0.6795	6.9399	3.0141	5.1712	1.6961
76 Ball_14_FE_16	2.6535	3.9022	0.6692	5.3666	1.8869	4.3617	1.5878
77 Ball_14_FE_17	1.4823	2.0705	0.5959	3.1818	10.1304	9.4519	1.1193
78 Ball_14_FE_18	1.4133	1.7679	0.4899	2.3659	6.0237	10.4584	1.1994
79 Ball_14_FE_19	1.8012	2.0345	0.5307	2.6912	8.8820	12.2382	1.1278
80 Ball_14_FE_20	1.4413	2.2233	0.4574	2.7879	9.4374	8.5563	1.0386
81 Ball_21_DE_1	4.4293	4.1469	1.7979	2.4680	24.4243	8.3278	1.5700
82 Ball_21_DE_2	2.3056	4.7063	1.8926	2.8236	23.9957	8.0181	1.5761
83 Ball_21_DE_3	1.6856	4.3233	1.8500	2.5487	22.7321	9.9110	1.6186
84 Ball_21_DE_4	1.8537	4.4140	1.9844	2.8132	24.3827	8.1304	1.6373
85 Ball_21_DE_5	3.3020	3.8325	1.8607	2.3058	24.3249	7.5820	1.6465
86 Ball_21_DE_6	5.5741	3.5249	1.8150	2.0844	20.6243	9.0677	1.5900
87 Ball_21_DE_7	6.2857	3.3072	1.6532	1.8632	22.2649	7.9503	1.4871
88 Ball_21_DE_8	5.7684	2.8717	1.5470	1.6026	22.2659	8.2618	1.1814
89 Ball_21_DE_9	3.8214	2.2554	0.9491	1.1404	27.3658	9.0954	0.7993
90 Ball_21_DE_10	4.7651	2.6377	1.1348	1.3822	31.7377	7.7160	0.9160
91 Ball_21_DE_11	4.7369	2.6586	1.1147	1.6172	23.4624	7.1869	1.0343

	E1	E2	E3	E4	E5	E6	E7
92 Ball_21_DE_12	6.3681	3.9565	1.7233	2.5539	21.5415	8.7168	1.6630
93 Ball_21_DE_13	5.1308	3.3891	1.7316	2.1476	24.4961	6.6110	1.5229
94 Ball_21_DE_14	2.0420	1.4527	0.8251	0.8832	30.2780	7.5969	0.7250
95 Ball_21_DE_15	3.4086	2.7607	1.6018	1.5679	24.9642	8.3432	1.4092
96 Ball_21_DE_16	2.9891	2.4888	1.5390	1.5624	26.3950	9.8407	1.1601
97 Ball_21_DE_17	4.9033	4.0310	1.7270	2.3530	24.0202	8.8901	1.5683
98 Ball_21_DE_18	4.2070	4.0416	1.7549	2.3373	22.5696	8.3223	1.4117
99 Ball_21_DE_19	4.5032	4.5930	1.7614	2.5785	22.4426	8.1688	1.6465
100 Ball_21_DE_20	3.4733	4.4569	1.9027	2.5616	21.7672	9.5656	1.6058

⋮

Global pool

- Global pool : includes all features of data

```
globalPool = [staticFeatures(:,1:end-1) envelopFeatures(:,1:end-1) wavletFeatures]
```

```
globalPool = 400×70 table
```

...

	mean	std	rms	sra	aav	energy	peak
1 Ball_07_DE_1	0.0153	0.1368	0.1376	0.0938	0.1103	143.3107	0.5204
2 Ball_07_DE_2	0.0150	0.1408	0.1416	0.0953	0.1126	151.6899	0.5258
3 Ball_07_DE_3	0.0150	0.1357	0.1365	0.0924	0.1090	141.0716	0.4754
4 Ball_07_DE_4	0.0148	0.1367	0.1375	0.0932	0.1100	143.0070	0.5580
5 Ball_07_DE_5	0.0142	0.1398	0.1405	0.0951	0.1123	149.4803	0.5671
6 Ball_07_DE_6	0.0135	0.1385	0.1392	0.0939	0.1109	146.5592	0.5921
7 Ball_07_DE_7	0.0135	0.1387	0.1394	0.0949	0.1117	146.9420	0.4756
8 Ball_07_DE_8	0.0130	0.1376	0.1382	0.0938	0.1107	144.5133	0.6070
9 Ball_07_DE_9	0.0123	0.1372	0.1377	0.0934	0.1101	143.5266	0.6070
10 Ball_07_DE_10	0.0122	0.1379	0.1384	0.0926	0.1100	144.9602	0.5495
11 Ball_07_DE_11	0.0120	0.1338	0.1344	0.0915	0.1078	136.6235	0.4699
12 Ball_07_DE_12	0.0119	0.1348	0.1354	0.0919	0.1083	138.6440	0.5791
13 Ball_07_DE_13	0.0117	0.1390	0.1395	0.0944	0.1116	147.1742	0.5105
14 Ball_07_DE_14	0.0114	0.1389	0.1393	0.0941	0.1111	146.8956	0.5161
15 Ball_07_DE_15	0.0111	0.1400	0.1405	0.0957	0.1126	149.2977	0.5391
16 Ball_07_DE_16	0.0111	0.1393	0.1397	0.0957	0.1124	147.7043	0.5313

	mean	std	rms	sra	aav	energy	peak
17 Ball_07_DE_17	0.0112	0.1405	0.1410	0.0947	0.1120	150.4082	0.5659
18 Ball_07_DE_18	0.0114	0.1474	0.1479	0.0996	0.1177	165.4518	0.5583
19 Ball_07_DE_19	0.0111	0.1383	0.1387	0.0935	0.1105	145.6731	0.5191
20 Ball_07_DE_20	0.0101	0.1437	0.1440	0.0964	0.1141	156.5564	0.6039
21 Ball_07_FE_1	0.0148	0.1758	0.1764	0.0967	0.1209	232.8513	1.5764
22 Ball_07_FE_2	0.0142	0.1421	0.1428	0.0859	0.1043	152.5042	1.4608
23 Ball_07_FE_3	0.0139	0.1385	0.1392	0.0862	0.1042	144.9878	1.1076
24 Ball_07_FE_4	0.0137	0.1327	0.1334	0.0824	0.0999	133.0800	1.0447
25 Ball_07_FE_5	0.0135	0.1296	0.1303	0.0823	0.0986	127.0273	1.0447
26 Ball_07_FE_6	0.0133	0.1201	0.1208	0.0765	0.0920	109.2144	0.7106
27 Ball_07_FE_7	0.0132	0.1411	0.1417	0.0834	0.1021	150.2320	1.1065
28 Ball_07_FE_8	0.0129	0.2044	0.2048	0.1051	0.1330	313.6251	2.1985
29 Ball_07_FE_9	0.0127	0.1686	0.1691	0.0901	0.1116	213.8183	2.1985
30 Ball_07_FE_10	0.0125	0.1430	0.1435	0.0856	0.1044	154.1317	1.2805
31 Ball_07_FE_11	0.0123	0.1905	0.1909	0.0978	0.1240	272.5504	1.9882
32 Ball_07_FE_12	0.0122	0.1901	0.1905	0.0947	0.1210	271.4129	1.9882
33 Ball_07_FE_13	0.0121	0.1337	0.1342	0.0810	0.0979	134.7549	1.5086
34 Ball_07_FE_14	0.0119	0.1319	0.1324	0.0802	0.0971	131.1298	1.5086
35 Ball_07_FE_15	0.0117	0.1210	0.1215	0.0784	0.0940	110.4552	0.7369
36 Ball_07_FE_16	0.0118	0.1228	0.1233	0.0801	0.0953	113.8094	1.0647
37 Ball_07_FE_17	0.0119	0.1278	0.1283	0.0769	0.0926	123.1795	1.8321
38 Ball_07_FE_18	0.0117	0.1218	0.1223	0.0806	0.0957	111.9408	1.0014
39 Ball_07_FE_19	0.0113	0.1144	0.1150	0.0762	0.0906	98.8396	0.6080
40 Ball_07_FE_20	0.0111	0.1126	0.1132	0.0745	0.0886	95.6783	0.6418
41 Ball_14_DE_1	0.0050	0.1793	0.1794	0.0960	0.1215	242.0458	1.3422
42 Ball_14_DE_2	0.0050	0.1661	0.1661	0.0892	0.1125	207.5782	1.6979
43 Ball_14_DE_3	0.0051	0.1890	0.1891	0.0946	0.1219	268.9895	1.9700
44 Ball_14_DE_4	0.0050	0.1970	0.1970	0.1000	0.1282	292.0527	1.8368
45 Ball_14_DE_5	0.0049	0.1563	0.1563	0.0840	0.1062	183.8092	1.2040
46 Ball_14_DE_6	0.0050	0.1510	0.1511	0.0800	0.1010	171.6986	1.4782
47 Ball_14_DE_7	0.0050	0.1208	0.1208	0.0634	0.0786	109.8539	1.4782
48 Ball_14_DE_8	0.0051	0.1615	0.1616	0.0813	0.1027	196.4539	2.2611
49 Ball_14_DE_9	0.0049	0.1273	0.1274	0.0658	0.0819	122.1374	2.2611

	mean	std	rms	sra	aav	energy	peak
50 Ball_14_DE_10	0.0046	0.0950	0.0951	0.0603	0.0723	68.0099	0.5762
51 Ball_14_DE_11	0.0045	0.0920	0.0921	0.0571	0.0689	63.8398	0.7342
52 Ball_14_DE_12	0.0042	0.0992	0.0992	0.0608	0.0734	74.0829	1.0990
53 Ball_14_DE_13	0.0040	0.0902	0.0903	0.0590	0.0703	61.3319	0.4763
54 Ball_14_DE_14	0.0041	0.0988	0.0989	0.0627	0.0752	73.6145	0.7961
55 Ball_14_DE_15	0.0045	0.1809	0.1810	0.0862	0.1122	246.3045	2.2782
56 Ball_14_DE_16	0.0045	0.1358	0.1359	0.0737	0.0922	138.8593	1.3697
57 Ball_14_DE_17	0.0046	0.1983	0.1983	0.1027	0.1321	295.8083	1.7714
58 Ball_14_DE_18	0.0046	0.1593	0.1593	0.0915	0.1138	190.9012	1.2498
59 Ball_14_DE_19	0.0048	0.1988	0.1989	0.1029	0.1319	297.5485	2.1960
60 Ball_14_DE_20	0.0046	0.1484	0.1485	0.0825	0.1032	165.4335	1.2688
61 Ball_14_FE_1	0.0064	0.2218	0.2218	0.1186	0.1502	370.9005	2.2089
62 Ball_14_FE_2	0.0063	0.1971	0.1972	0.1139	0.1410	292.9923	1.4573
63 Ball_14_FE_3	0.0064	0.2616	0.2616	0.1382	0.1759	515.9767	2.4134
64 Ball_14_FE_4	0.0062	0.2305	0.2306	0.1269	0.1593	400.7118	2.0044
65 Ball_14_FE_5	0.0064	0.2844	0.2845	0.1400	0.1824	609.9034	2.9467
66 Ball_14_FE_6	0.0062	0.2852	0.2853	0.1426	0.1852	613.3300	2.9467
67 Ball_14_FE_7	0.0061	0.2259	0.2259	0.1292	0.1608	384.7091	1.7532
68 Ball_14_FE_8	0.0062	0.2372	0.2373	0.1190	0.1538	424.2454	1.8723
69 Ball_14_FE_9	0.0063	0.2365	0.2366	0.1074	0.1426	421.7594	2.2825
70 Ball_14_FE_10	0.0066	0.2968	0.2968	0.1470	0.1906	663.9488	3.0812
71 Ball_14_FE_11	0.0063	0.2584	0.2584	0.1157	0.1528	503.3821	3.0812
72 Ball_14_FE_12	0.0061	0.2233	0.2233	0.1097	0.1408	375.9457	2.4394
73 Ball_14_FE_13	0.0062	0.2398	0.2399	0.1168	0.1505	433.7901	2.4394
74 Ball_14_FE_14	0.0064	0.1394	0.1396	0.0873	0.1054	146.8258	0.9406
75 Ball_14_FE_15	0.0060	0.1297	0.1299	0.0827	0.0992	127.1156	0.9955
76 Ball_14_FE_16	0.0057	0.1507	0.1508	0.0903	0.1105	171.4106	1.1565
77 Ball_14_FE_17	0.0057	0.2312	0.2312	0.1128	0.1454	402.9626	2.6292
78 Ball_14_FE_18	0.0057	0.2348	0.2348	0.1256	0.1594	415.5466	1.6105
79 Ball_14_FE_19	0.0055	0.2261	0.2262	0.1185	0.1506	385.6383	2.5032
80 Ball_14_FE_20	0.0054	0.2128	0.2129	0.1089	0.1387	340.5615	2.5983
81 Ball_21_DE_1	0.0212	0.1154	0.1173	0.0771	0.0919	103.6988	0.5838
82 Ball_21_DE_2	0.0027	0.1137	0.1137	0.0740	0.0884	97.3176	0.5838

	mean	std	rms	sra	aav	energy	peak
83 Ball_21_DE_3	-0.0074	0.1170	0.1172	0.0763	0.0912	103.4682	0.5118
84 Ball_21_DE_4	0.0075	0.1174	0.1176	0.0761	0.0911	104.1806	0.5987
85 Ball_21_DE_5	0.0184	0.1258	0.1271	0.0830	0.0990	121.6876	0.5625
86 Ball_21_DE_6	0.0264	0.1248	0.1276	0.0844	0.1002	122.5783	0.5625
87 Ball_21_DE_7	0.0308	0.1320	0.1355	0.0880	0.1052	138.3069	0.9027
88 Ball_21_DE_8	0.0321	0.1423	0.1459	0.0877	0.1064	160.2819	1.2883
89 Ball_21_DE_9	0.0317	0.1749	0.1777	0.0993	0.1236	237.8792	1.5886
90 Ball_21_DE_10	0.0306	0.1534	0.1564	0.0906	0.1116	184.3139	1.6596
91 Ball_21_DE_11	0.0292	0.1476	0.1504	0.0882	0.1081	170.4178	1.6596
92 Ball_21_DE_12	0.0282	0.1182	0.1215	0.0789	0.0943	111.1395	0.5593
93 Ball_21_DE_13	0.0267	0.1272	0.1300	0.0827	0.0995	127.2926	0.8513
94 Ball_21_DE_14	0.0250	0.1972	0.1987	0.1084	0.1361	297.4556	1.6179
95 Ball_21_DE_15	0.0236	0.1440	0.1459	0.0906	0.1099	160.3455	0.8749
96 Ball_21_DE_16	0.0226	0.1531	0.1547	0.0958	0.1164	180.2927	0.8749
97 Ball_21_DE_17	0.0216	0.1172	0.1192	0.0774	0.0927	106.9352	0.5302
98 Ball_21_DE_18	0.0203	0.1182	0.1199	0.0786	0.0937	108.2648	0.5331
99 Ball_21_DE_19	0.0192	0.1157	0.1172	0.0777	0.0922	103.4842	0.5331
100 Ball_21_DE_20	0.0181	0.1150	0.1164	0.0763	0.0908	101.8811	0.5398

⋮

Confusion matrix

- 4 : staticFeatures / envelopFeatures / waveletFeatures / globalPool
- Function 'normalization' returns z score. Center value 0, Standard deviation 1

Normalization

```
normstaticFeature  = normalizeTbl(staticFeatures);
normenvelopFeature = normalizeTbl(envelopFeatures);
normwaveletFeature = normalizeTbl(wavletFeatures);
normglobalPool     = normalizeTbl(globalPool);

normglobalPool
```

```
normglobalPool = 400×70 table
```

...

	mean	std	rms	sra	aav	energy	peak
1 Ball_07_DE_1	-0.2014	-0.7292	-0.7272	-0.5988	-0.6491	-0.6228	-0.9741
2 Ball_07_DE_2	-0.2079	-0.7131	-0.7115	-0.5854	-0.6339	-0.6182	-0.9708
3 Ball_07_DE_3	-0.2090	-0.7334	-0.7315	-0.6110	-0.6573	-0.6241	-1.0019
4 Ball_07_DE_4	-0.2133	-0.7295	-0.7278	-0.6037	-0.6506	-0.6230	-0.9509
5 Ball_07_DE_5	-0.2247	-0.7169	-0.7156	-0.5871	-0.6360	-0.6194	-0.9453
6 Ball_07_DE_6	-0.2412	-0.7222	-0.7211	-0.5976	-0.6448	-0.6210	-0.9299
7 Ball_07_DE_7	-0.2407	-0.7214	-0.7204	-0.5886	-0.6398	-0.6208	-1.0018
8 Ball_07_DE_8	-0.2509	-0.7259	-0.7250	-0.5990	-0.6463	-0.6222	-0.9206
9 Ball_07_DE_9	-0.2658	-0.7276	-0.7268	-0.6021	-0.6501	-0.6227	-0.9206
10 Ball_07_DE_10	-0.2682	-0.7248	-0.7241	-0.6091	-0.6507	-0.6219	-0.9562
11 Ball_07_DE_11	-0.2725	-0.7409	-0.7401	-0.6193	-0.6652	-0.6265	-1.0053
12 Ball_07_DE_12	-0.2764	-0.7369	-0.7362	-0.6156	-0.6618	-0.6254	-0.9379
13 Ball_07_DE_13	-0.2808	-0.7203	-0.7199	-0.5932	-0.6406	-0.6207	-0.9802
14 Ball_07_DE_14	-0.2854	-0.7208	-0.7205	-0.5960	-0.6436	-0.6208	-0.9768
15 Ball_07_DE_15	-0.2933	-0.7161	-0.7160	-0.5811	-0.6338	-0.6195	-0.9626
16 Ball_07_DE_16	-0.2926	-0.7191	-0.7189	-0.5809	-0.6354	-0.6204	-0.9674
17 Ball_07_DE_17	-0.2908	-0.7140	-0.7139	-0.5907	-0.6374	-0.6189	-0.9460
18 Ball_07_DE_18	-0.2864	-0.6864	-0.6866	-0.5463	-0.6002	-0.6105	-0.9507
19 Ball_07_DE_19	-0.2932	-0.7230	-0.7228	-0.6010	-0.6473	-0.6215	-0.9749
20 Ball_07_DE_20	-0.3137	-0.7014	-0.7017	-0.5752	-0.6240	-0.6155	-0.9225
21 Ball_07_FE_1	-0.2135	-0.5727	-0.5733	-0.5725	-0.5792	-0.5730	-0.3217
22 Ball_07_FE_2	-0.2251	-0.7079	-0.7067	-0.6702	-0.6885	-0.6177	-0.3931
23 Ball_07_FE_3	-0.2323	-0.7221	-0.7209	-0.6674	-0.6886	-0.6219	-0.6113
24 Ball_07_FE_4	-0.2355	-0.7456	-0.7440	-0.7015	-0.7170	-0.6285	-0.6502
25 Ball_07_FE_5	-0.2409	-0.7578	-0.7562	-0.7027	-0.7256	-0.6319	-0.6502
26 Ball_07_FE_6	-0.2457	-0.7959	-0.7938	-0.7548	-0.7687	-0.6418	-0.8567
27 Ball_07_FE_7	-0.2483	-0.7118	-0.7110	-0.6930	-0.7029	-0.6190	-0.6120
28 Ball_07_FE_8	-0.2534	-0.4583	-0.4609	-0.4966	-0.4999	-0.5280	0.0627
29 Ball_07_FE_9	-0.2588	-0.6016	-0.6025	-0.6317	-0.6407	-0.5836	0.0627
30 Ball_07_FE_10	-0.2622	-0.7042	-0.7037	-0.6726	-0.6873	-0.6168	-0.5045
31 Ball_07_FE_11	-0.2662	-0.5139	-0.5160	-0.5620	-0.5591	-0.5509	-0.0672
32 Ball_07_FE_12	-0.2700	-0.5155	-0.5176	-0.5907	-0.5790	-0.5515	-0.0672
33 Ball_07_FE_13	-0.2716	-0.7416	-0.7407	-0.7144	-0.7300	-0.6276	-0.3636

	mean	std	rms	sra	aav	energy	peak
34 Ball_07_FE_14	-0.2747	-0.7488	-0.7479	-0.7213	-0.7356	-0.6296	-0.3636
35 Ball_07_FE_15	-0.2798	-0.7925	-0.7911	-0.7374	-0.7555	-0.6411	-0.8404
36 Ball_07_FE_16	-0.2786	-0.7852	-0.7838	-0.7223	-0.7472	-0.6392	-0.6379
37 Ball_07_FE_17	-0.2761	-0.7652	-0.7641	-0.7512	-0.7650	-0.6340	-0.1637
38 Ball_07_FE_18	-0.2797	-0.7893	-0.7879	-0.7175	-0.7446	-0.6403	-0.6769
39 Ball_07_FE_19	-0.2876	-0.8188	-0.8171	-0.7573	-0.7779	-0.6476	-0.9201
40 Ball_07_FE_20	-0.2932	-0.8259	-0.8243	-0.7735	-0.7910	-0.6493	-0.8992
41 Ball_14_DE_1	-0.4250	-0.5587	-0.5616	-0.5790	-0.5756	-0.5679	-0.4664
42 Ball_14_DE_2	-0.4255	-0.6118	-0.6142	-0.6398	-0.6346	-0.5871	-0.2466
43 Ball_14_DE_3	-0.4228	-0.5197	-0.5230	-0.5917	-0.5731	-0.5529	-0.0785
44 Ball_14_DE_4	-0.4258	-0.4879	-0.4915	-0.5423	-0.5316	-0.5401	-0.1608
45 Ball_14_DE_5	-0.4279	-0.6511	-0.6531	-0.6872	-0.6754	-0.6003	-0.5518
46 Ball_14_DE_6	-0.4250	-0.6721	-0.6738	-0.7229	-0.7097	-0.6070	-0.3824
47 Ball_14_DE_7	-0.4253	-0.7934	-0.7938	-0.8735	-0.8567	-0.6414	-0.3824
48 Ball_14_DE_8	-0.4224	-0.6300	-0.6321	-0.7112	-0.6985	-0.5932	0.1014
49 Ball_14_DE_9	-0.4287	-0.7670	-0.7677	-0.8521	-0.8349	-0.6346	0.1014
50 Ball_14_DE_10	-0.4333	-0.8966	-0.8959	-0.9019	-0.8977	-0.6647	-0.9397
51 Ball_14_DE_11	-0.4371	-0.9085	-0.9077	-0.9306	-0.9201	-0.6670	-0.8420
52 Ball_14_DE_12	-0.4420	-0.8799	-0.8795	-0.8972	-0.8907	-0.6613	-0.6166
53 Ball_14_DE_13	-0.4477	-0.9157	-0.9149	-0.9136	-0.9107	-0.6684	-1.0014
54 Ball_14_DE_14	-0.4455	-0.8811	-0.8807	-0.8801	-0.8786	-0.6616	-0.8038
55 Ball_14_DE_15	-0.4366	-0.5523	-0.5554	-0.6672	-0.6365	-0.5655	0.1119
56 Ball_14_DE_16	-0.4364	-0.7331	-0.7342	-0.7801	-0.7673	-0.6253	-0.4494
57 Ball_14_DE_17	-0.4348	-0.4828	-0.4865	-0.5184	-0.5060	-0.5380	-0.2012
58 Ball_14_DE_18	-0.4340	-0.6391	-0.6412	-0.6197	-0.6263	-0.5963	-0.5235
59 Ball_14_DE_19	-0.4300	-0.4805	-0.4842	-0.5159	-0.5076	-0.5370	0.0611
60 Ball_14_DE_20	-0.4352	-0.6825	-0.6842	-0.7011	-0.6952	-0.6105	-0.5118
61 Ball_14_FE_1	-0.3946	-0.3887	-0.3932	-0.3742	-0.3879	-0.4962	0.0691
62 Ball_14_FE_2	-0.3971	-0.4876	-0.4911	-0.4170	-0.4481	-0.5395	-0.3953
63 Ball_14_FE_3	-0.3954	-0.2291	-0.2353	-0.1970	-0.2196	-0.4154	0.1954
64 Ball_14_FE_4	-0.3992	-0.3536	-0.3585	-0.2989	-0.3280	-0.4796	-0.0572
65 Ball_14_FE_5	-0.3958	-0.1376	-0.1448	-0.1809	-0.1771	-0.3632	0.5249
66 Ball_14_FE_6	-0.3996	-0.1344	-0.1416	-0.1573	-0.1582	-0.3613	0.5249

	mean	std	rms	sra	aav	energy	peak
67 Ball_14_FE_7	-0.4020	-0.3722	-0.3770	-0.2783	-0.3180	-0.4885	-0.2124
68 Ball_14_FE_8	-0.4000	-0.3268	-0.3321	-0.3705	-0.3639	-0.4665	-0.1389
69 Ball_14_FE_9	-0.3963	-0.3296	-0.3348	-0.4754	-0.4372	-0.4679	0.1146
70 Ball_14_FE_10	-0.3916	-0.0882	-0.0959	-0.1172	-0.1232	-0.3331	0.6081
71 Ball_14_FE_11	-0.3983	-0.2419	-0.2481	-0.4005	-0.3706	-0.4225	0.6081
72 Ball_14_FE_12	-0.4018	-0.3826	-0.3873	-0.4548	-0.4492	-0.4934	0.2115
73 Ball_14_FE_13	-0.3986	-0.3162	-0.3215	-0.3905	-0.3856	-0.4612	0.2115
74 Ball_14_FE_14	-0.3951	-0.7185	-0.7195	-0.6573	-0.6810	-0.6209	-0.7145
75 Ball_14_FE_15	-0.4035	-0.7574	-0.7580	-0.6991	-0.7214	-0.6318	-0.6806
76 Ball_14_FE_16	-0.4095	-0.6733	-0.6749	-0.6303	-0.6476	-0.6072	-0.5811
77 Ball_14_FE_17	-0.4095	-0.3510	-0.3560	-0.4267	-0.4191	-0.4783	0.3288
78 Ball_14_FE_18	-0.4097	-0.3366	-0.3418	-0.3106	-0.3273	-0.4713	-0.3006
79 Ball_14_FE_19	-0.4150	-0.3711	-0.3759	-0.3751	-0.3851	-0.4880	0.2509
80 Ball_14_FE_20	-0.4158	-0.4245	-0.4288	-0.4624	-0.4630	-0.5131	0.3097
81 Ball_21_DE_1	-0.0745	-0.8147	-0.8077	-0.7492	-0.7694	-0.6449	-0.9350
82 Ball_21_DE_2	-0.4758	-0.8218	-0.8222	-0.7779	-0.7925	-0.6484	-0.9350
83 Ball_21_DE_3	-0.6955	-0.8085	-0.8082	-0.7572	-0.7739	-0.6450	-0.9794
84 Ball_21_DE_4	-0.3704	-0.8069	-0.8066	-0.7583	-0.7743	-0.6446	-0.9257
85 Ball_21_DE_5	-0.1348	-0.7732	-0.7689	-0.6965	-0.7228	-0.6349	-0.9481
86 Ball_21_DE_6	0.0397	-0.7770	-0.7671	-0.6840	-0.7149	-0.6344	-0.9481
87 Ball_21_DE_7	0.1355	-0.7484	-0.7356	-0.6507	-0.6826	-0.6256	-0.7380
88 Ball_21_DE_8	0.1625	-0.7069	-0.6944	-0.6542	-0.6746	-0.6134	-0.4997
89 Ball_21_DE_9	0.1541	-0.5764	-0.5682	-0.5485	-0.5618	-0.5702	-0.3141
90 Ball_21_DE_10	0.1316	-0.6625	-0.6526	-0.6277	-0.6403	-0.6000	-0.2703
91 Ball_21_DE_11	0.1010	-0.6859	-0.6764	-0.6493	-0.6634	-0.6077	-0.2703
92 Ball_21_DE_12	0.0779	-0.8037	-0.7912	-0.7337	-0.7534	-0.6407	-0.9501
93 Ball_21_DE_13	0.0471	-0.7674	-0.7574	-0.6991	-0.7198	-0.6317	-0.7697
94 Ball_21_DE_14	0.0098	-0.4872	-0.4848	-0.4666	-0.4800	-0.5370	-0.2961
95 Ball_21_DE_15	-0.0216	-0.7002	-0.6943	-0.6275	-0.6513	-0.6133	-0.7551
96 Ball_21_DE_16	-0.0424	-0.6639	-0.6594	-0.5804	-0.6091	-0.6022	-0.7551
97 Ball_21_DE_17	-0.0652	-0.8076	-0.8004	-0.7469	-0.7642	-0.6431	-0.9681
98 Ball_21_DE_18	-0.0924	-0.8037	-0.7975	-0.7357	-0.7574	-0.6423	-0.9663
99 Ball_21_DE_19	-0.1173	-0.8138	-0.8081	-0.7442	-0.7675	-0.6450	-0.9663

	mean	std	rms	sra	aav	energy	peak
100 Ball_21_DE_20	-0.1417	-0.8163	-0.8113	-0.7569	-0.7765	-0.6459	-0.9622

⋮

Training

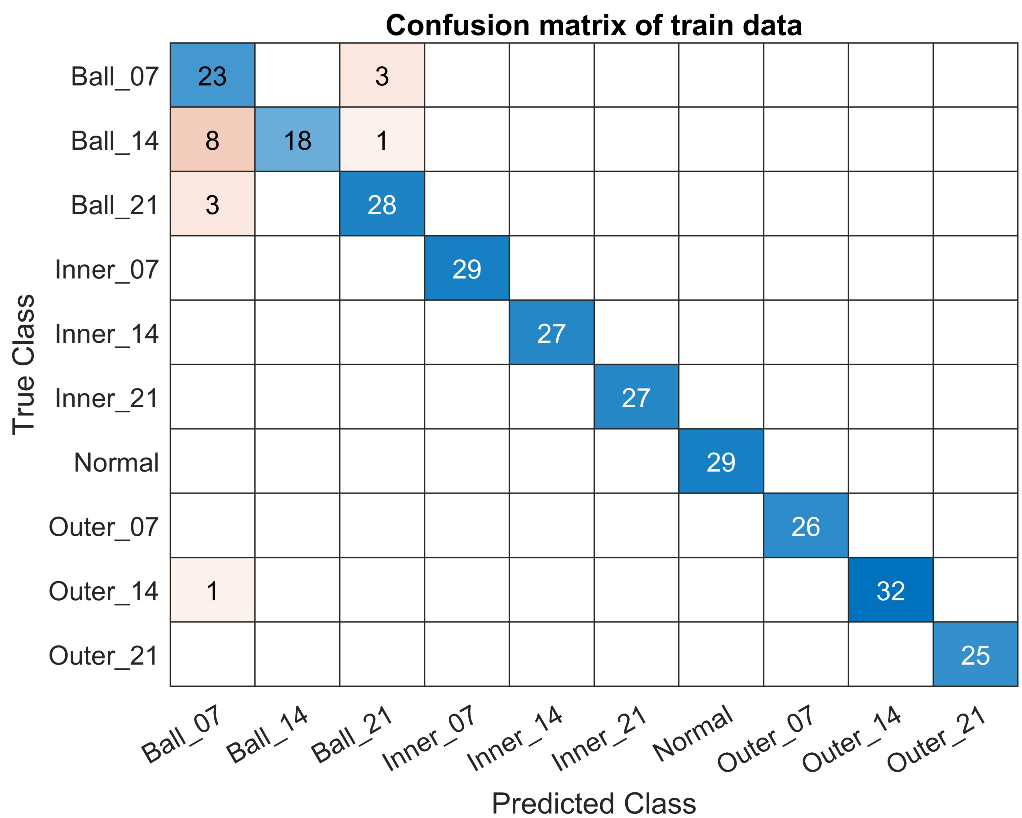
- kfold loss : k fold를 했을 때, 교차검증된
- loss : 다른 특정 데이터셋에서 주로 사용하는데 유용
- 0.3 percent cvpartition

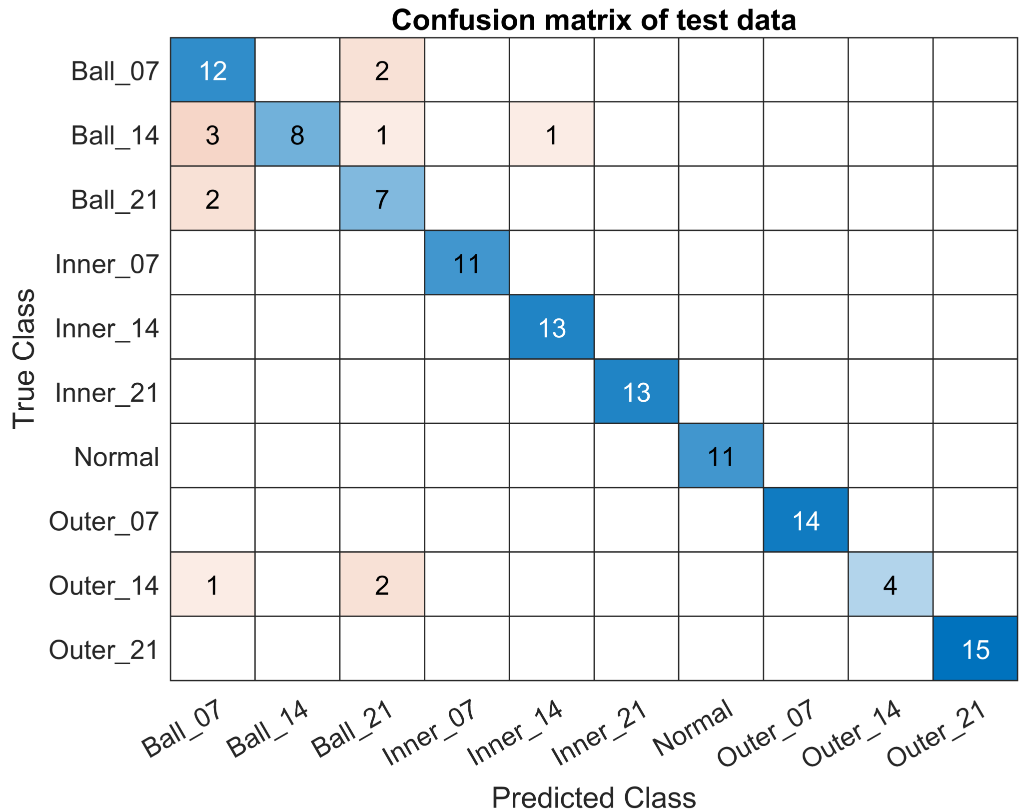
```
[stcTrain, stcTrainCls, stcTest, stcTestCls] = trainTest(normstaticFeature);
[envTrain, envTrainCls, envTest, envTestCls] = trainTest(normenvelopFeature);
[waveTrain, waveTrainCls, waveTest, waveTestCls] = trainTest(normwaveletFeature);
[poolTrain, poolTrainCls, poolTest, poolTestCls] = trainTest(normglobalPool);
```

Classification : statistical feature

1) KNN

```
stcKNNloss = KNN(stcTrain, stcTrainCls, stcTest, stcTestCls);
```

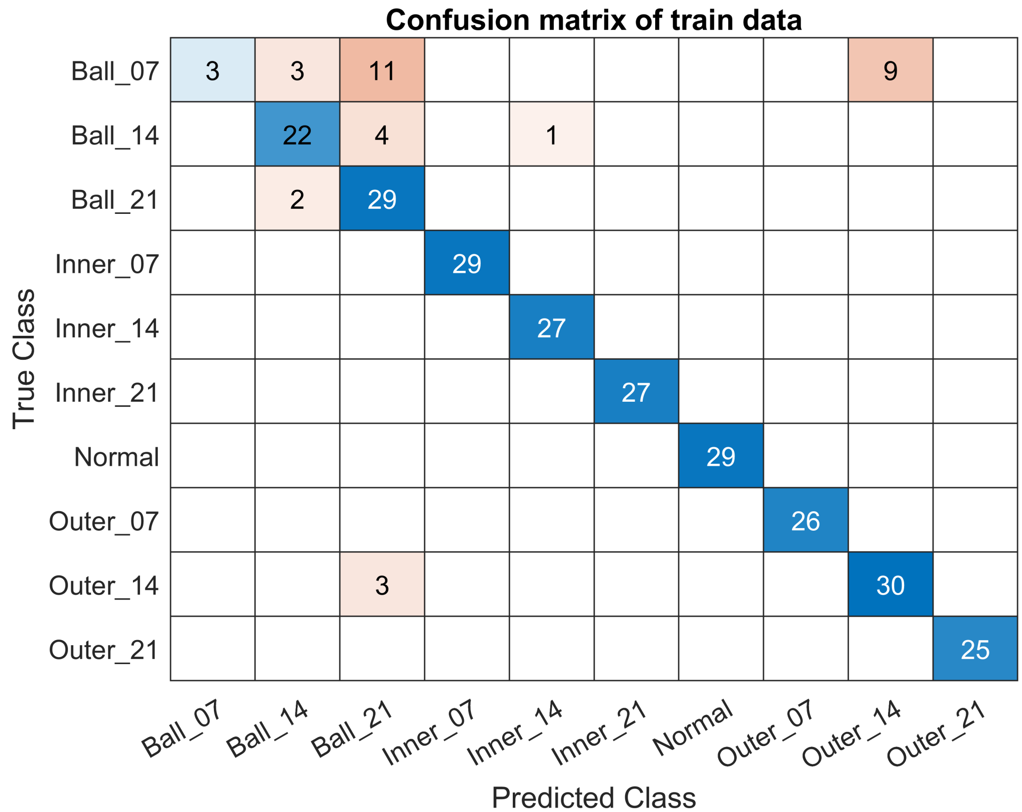


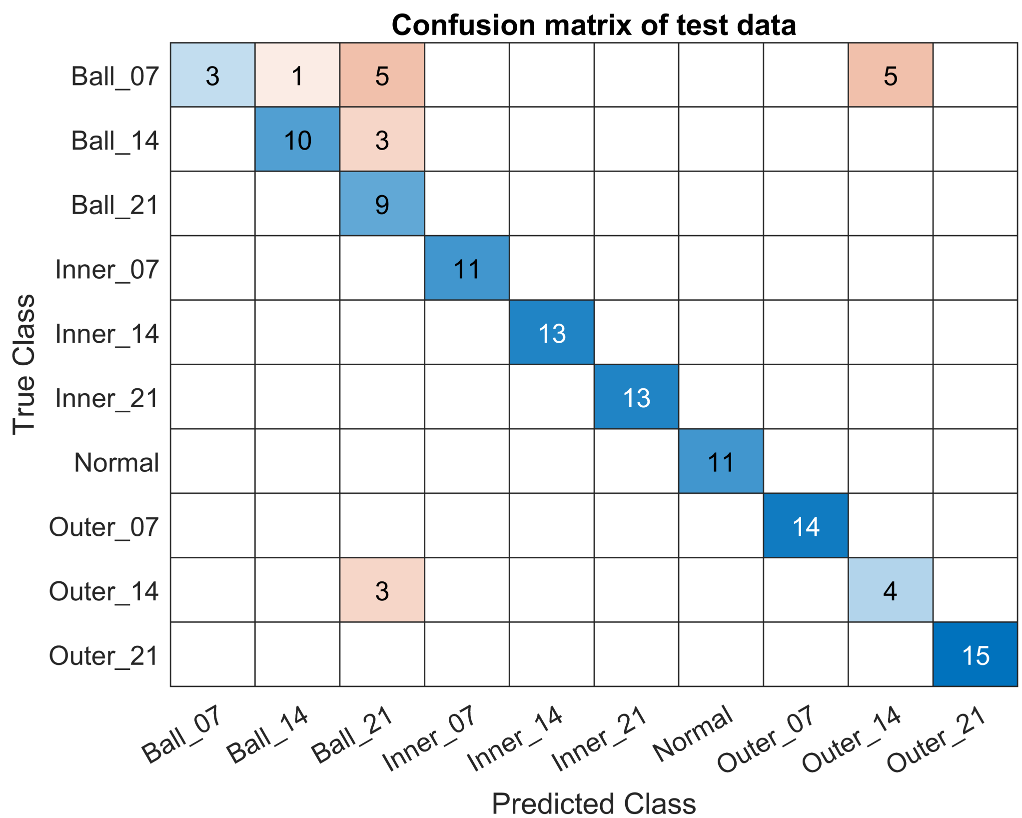


2) SVM

```
stcSVMloss = SVM(stcTrain, stcTrainCls, stcTest, stcTestCls);
```

```
ResubErr_SVM = 0.1179
cvErr_SVM = 0.1714
```

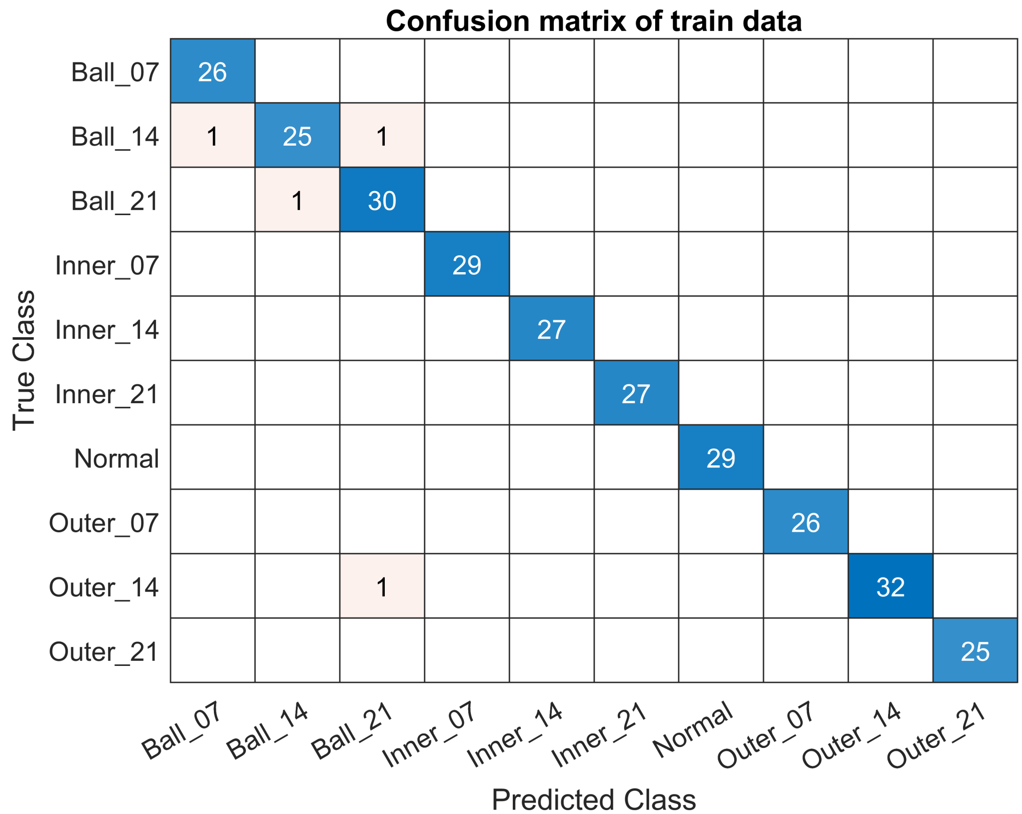


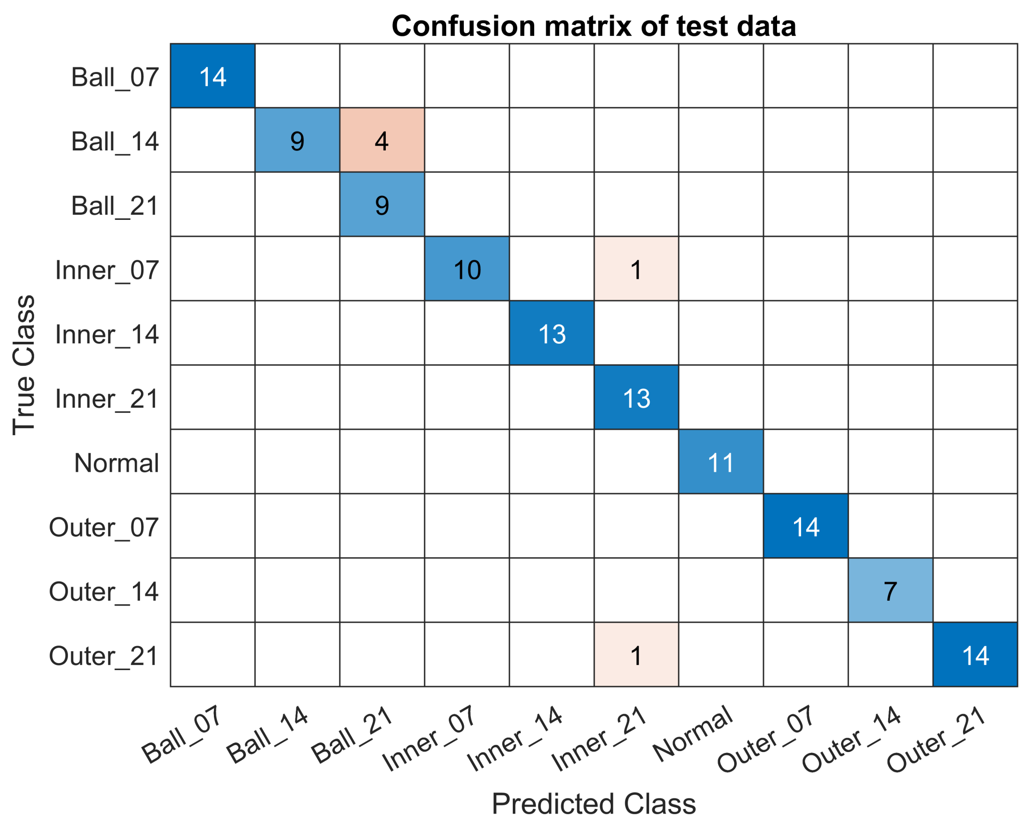


3) Deicision tree

```
stcTREEloss = decisionTree(stcTrain, stcTrainCls, stcTest, stcTestCls);
```

```
ResubErr_Tree = 0.0143
cvErrTree = 0.0750
```

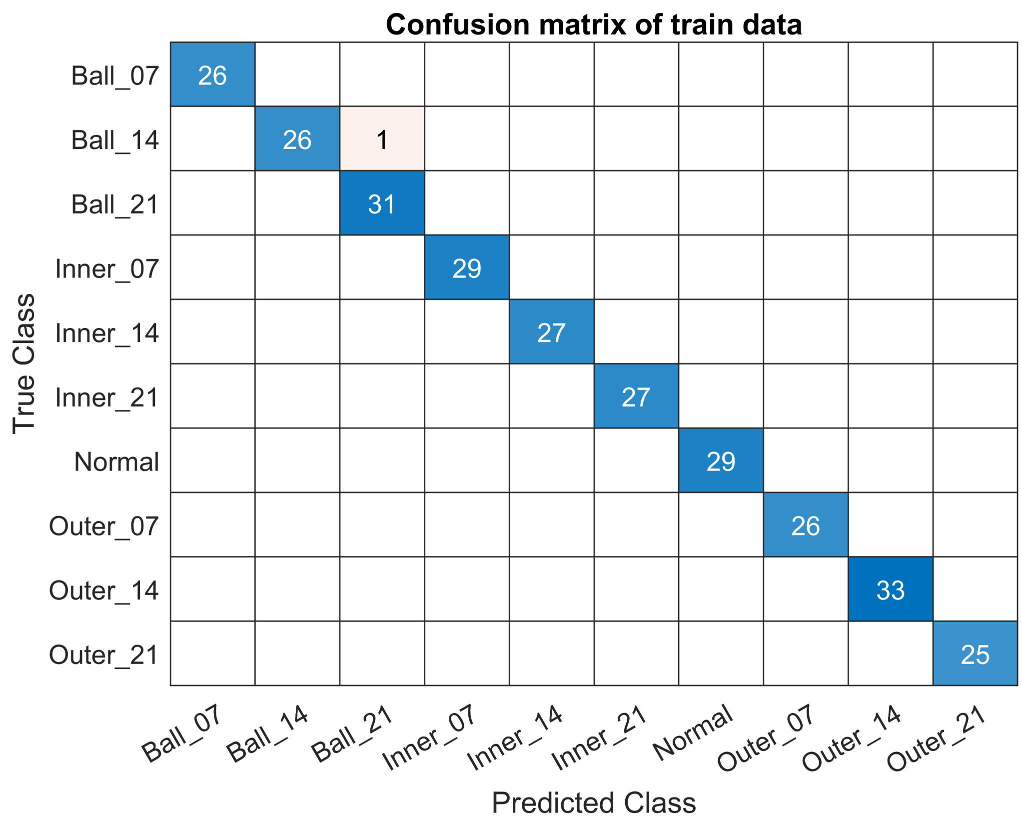


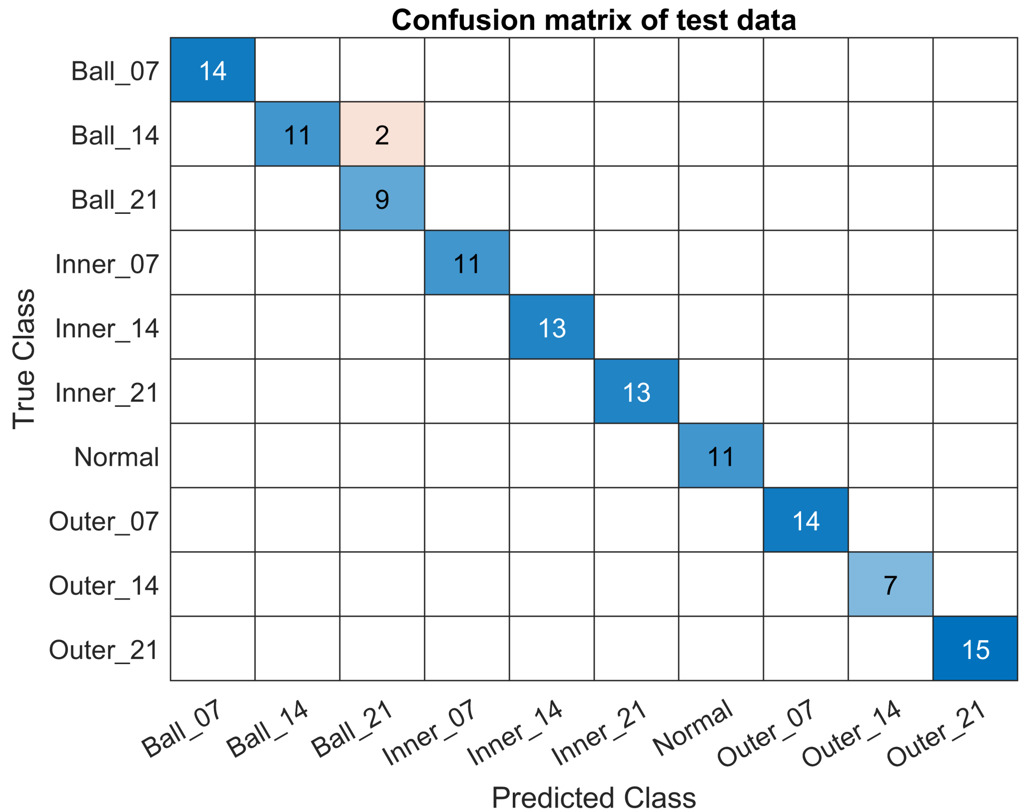


Classification : envelop feature

1) KNN

```
envKNNloss = KNN(envTrain, envTrainCls, envTest, envTestCls);
```

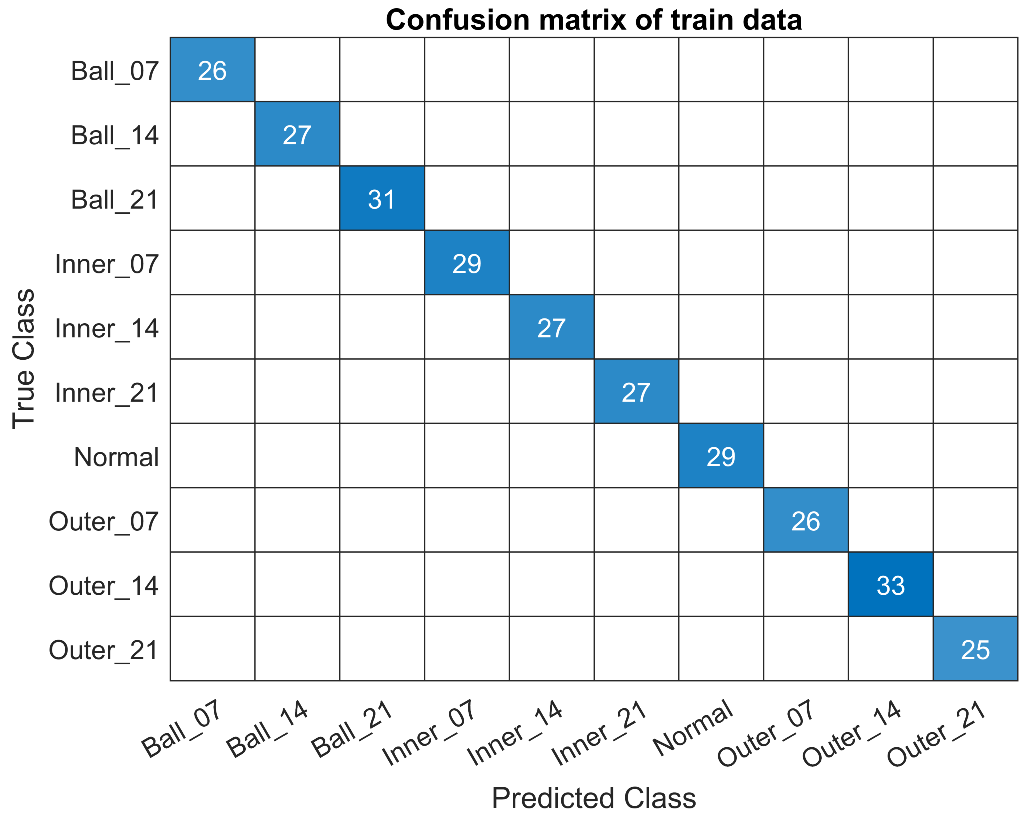


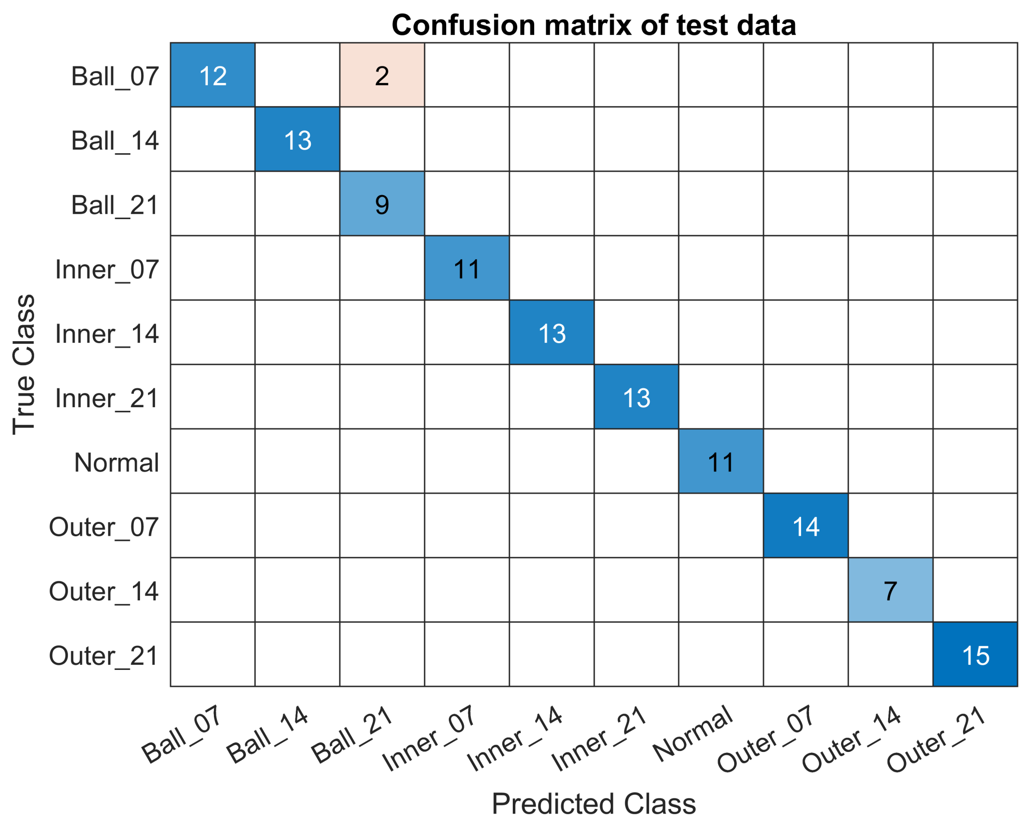


2) SVM

```
envSVMloss = SVM(envTrain, envTrainCls, envTest, envTestCls);
```

```
ResubErr_SVM = 0
cvErr_SVM = 0.0464
```

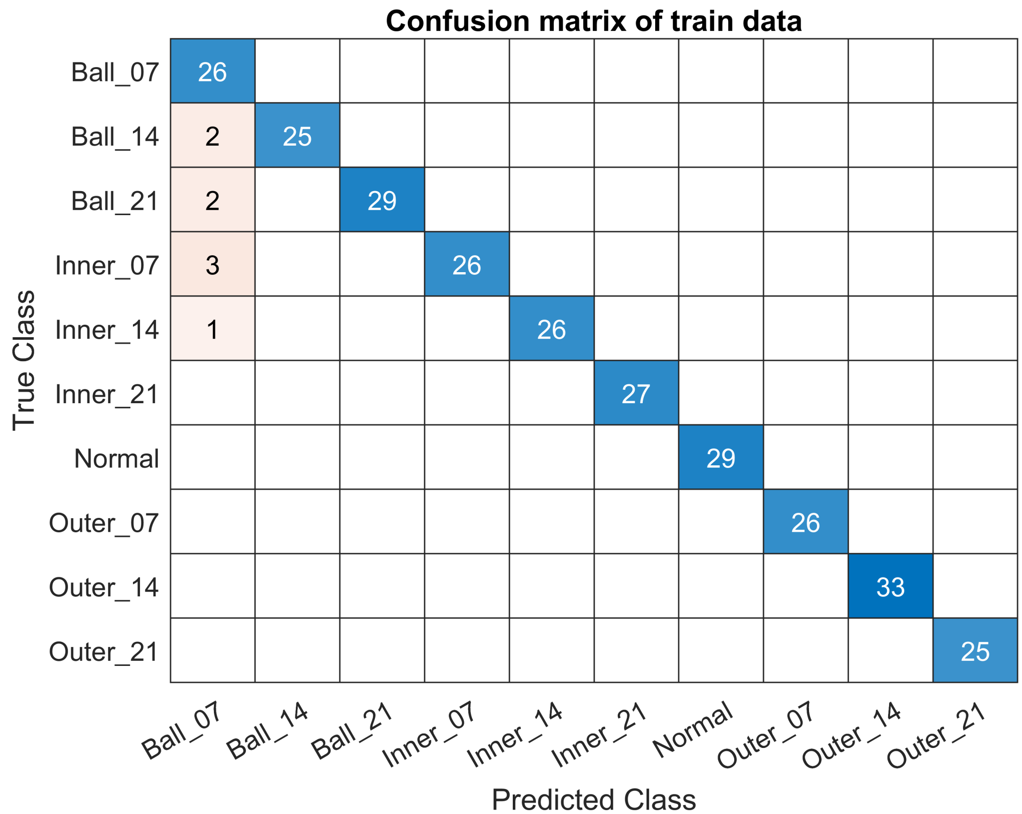


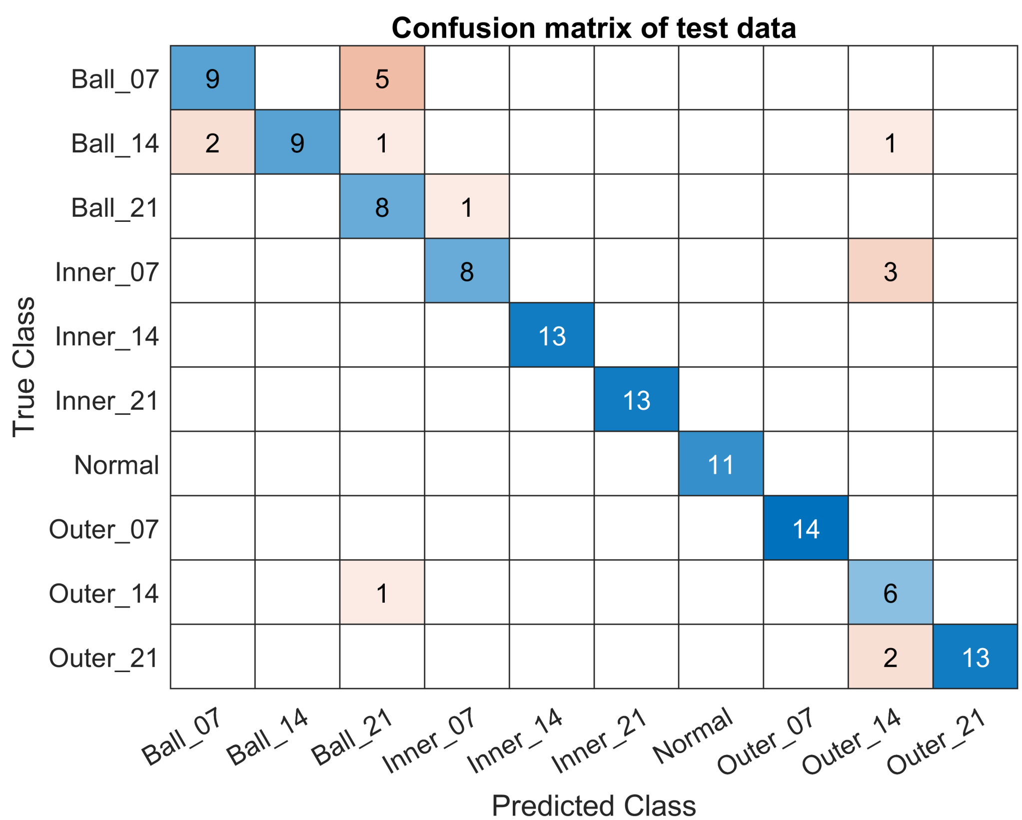


3) Deicision tree

```
envTREEloss = decisionTree(envTrain, envTrainCls, envTest, envTestCls);
```

```
ResubErr_Tree = 0.0286
cvErrTree = 0.1571
```

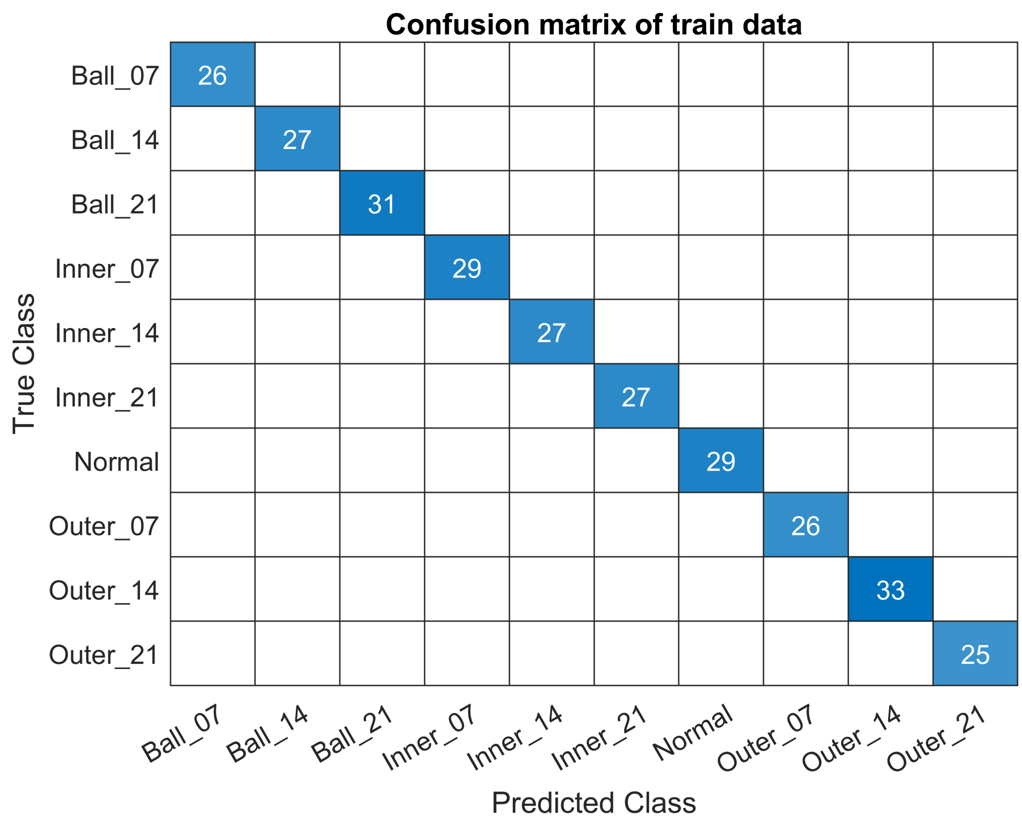


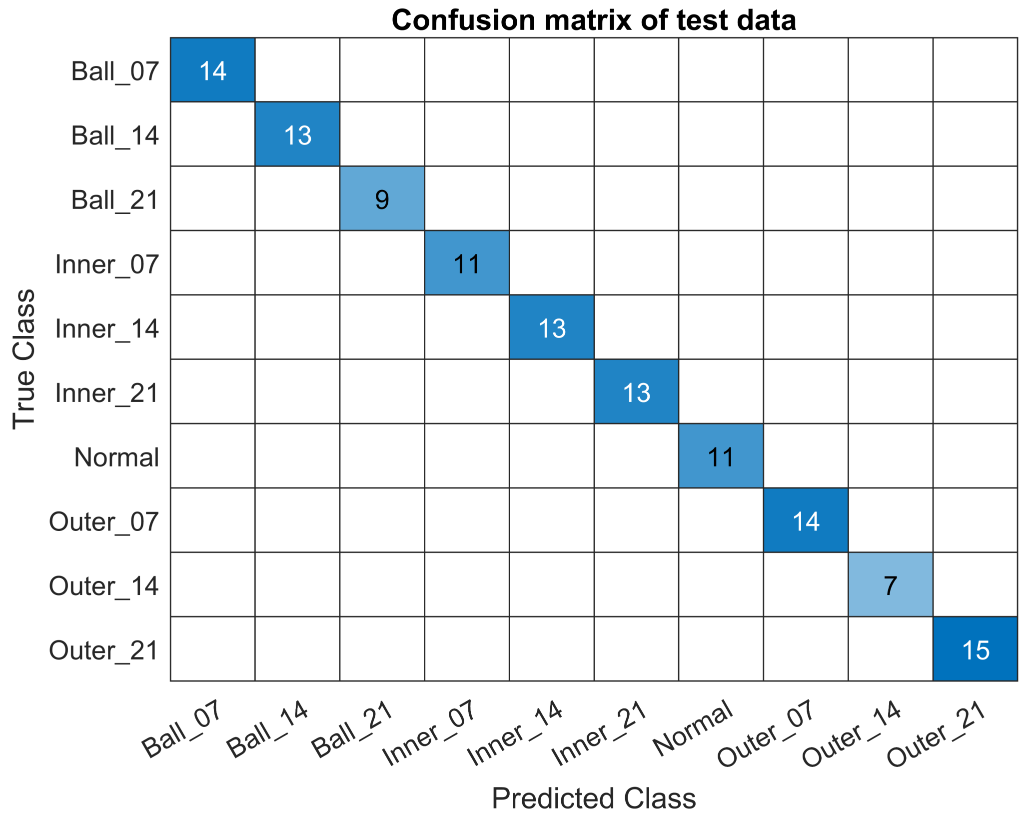


Classification : wavelet feature

1) KNN

```
waveKNNloss = KNN(waveTrain, waveTrainCls, waveTest, waveTestCls);
```

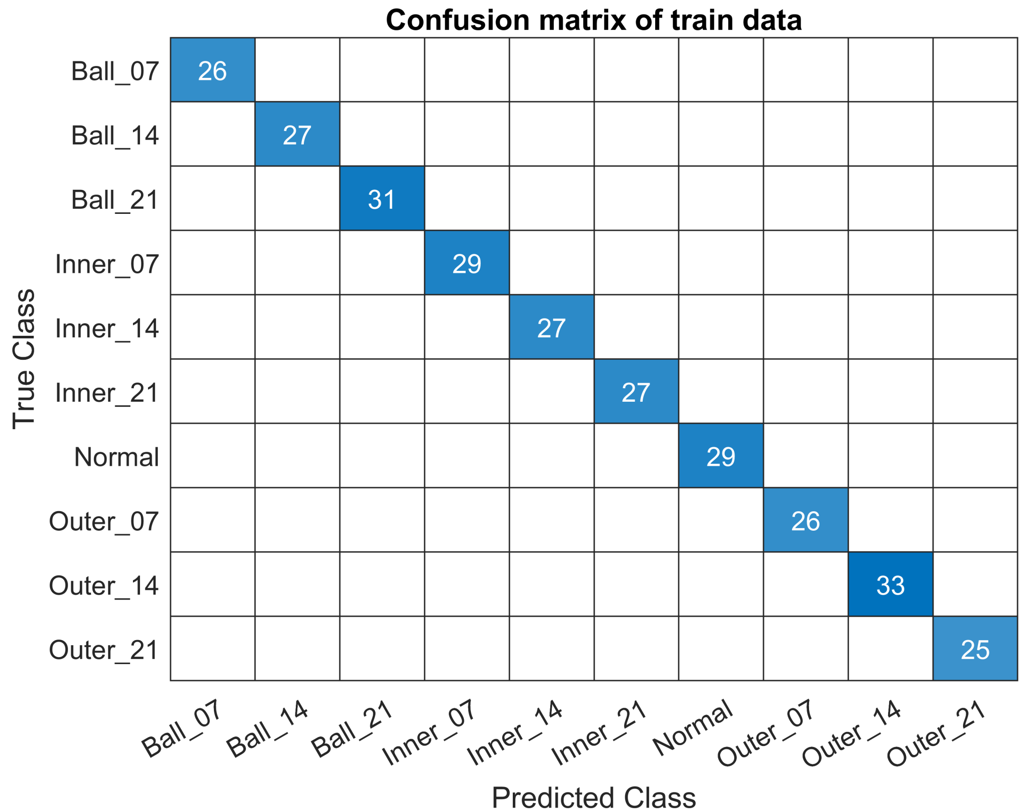


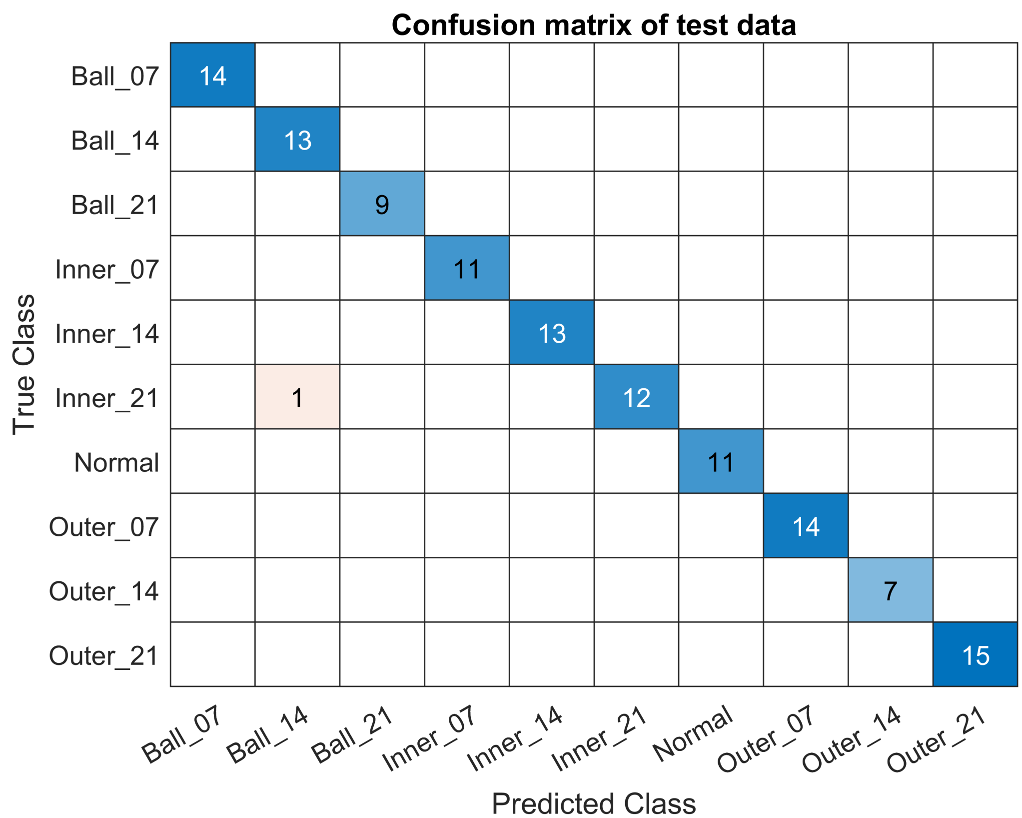


2) SVM

```
waveSVMloss = SVM(waveTrain, waveTrainCls, waveTest, waveTestCls);
```

```
ResubErr_SVM = 0
cvErr_SVM = 0.0071
```

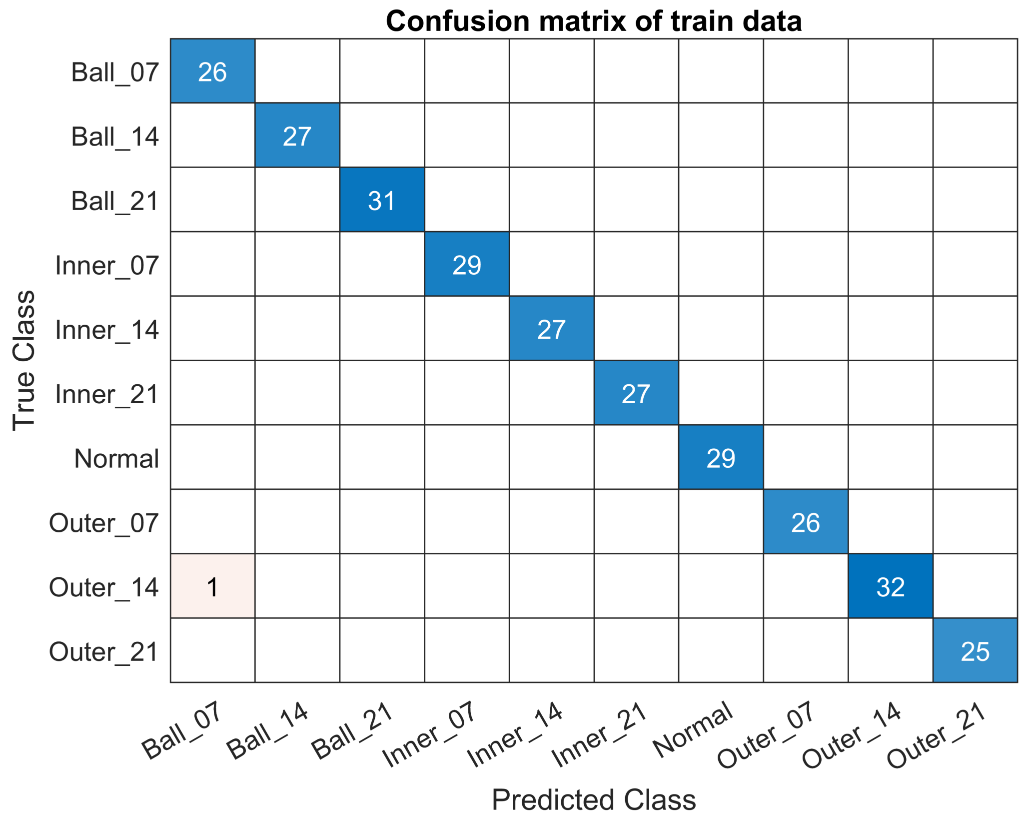


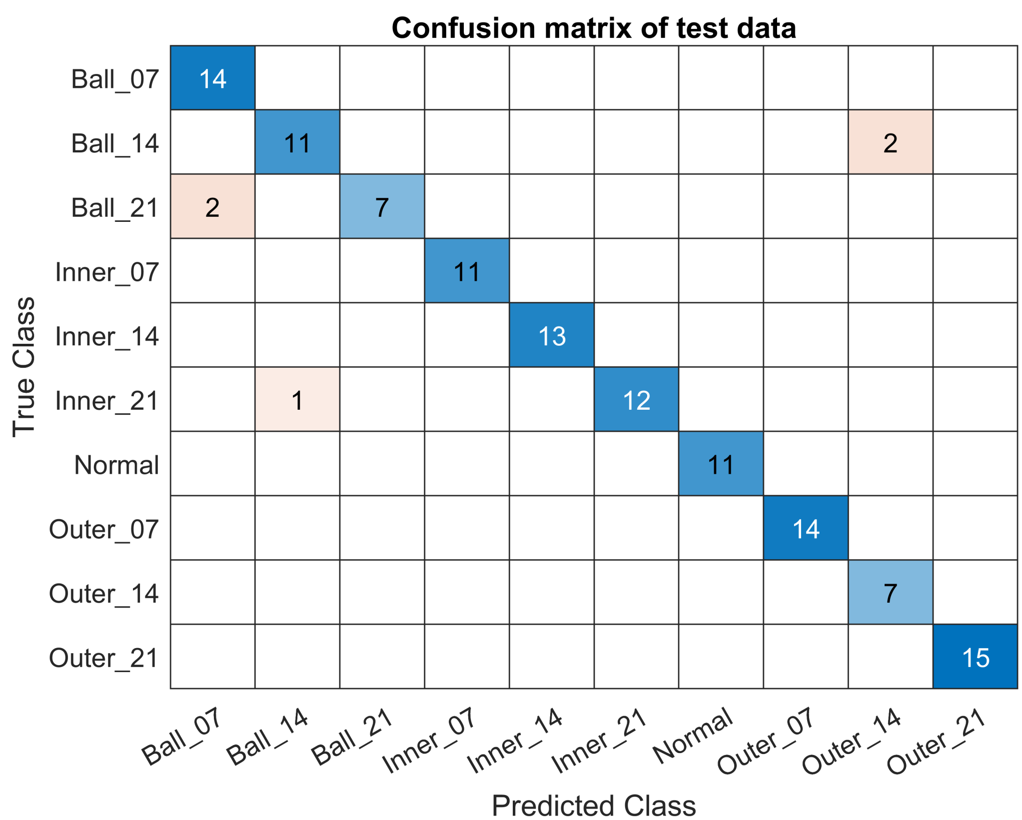


3) Deicision tree

```
waveTREEloss = decisionTree(waveTrain, waveTrainCls, waveTest, waveTestCls);
```

```
ResubErr_Tree = 0.0036
cvErrTree = 0.1107
```

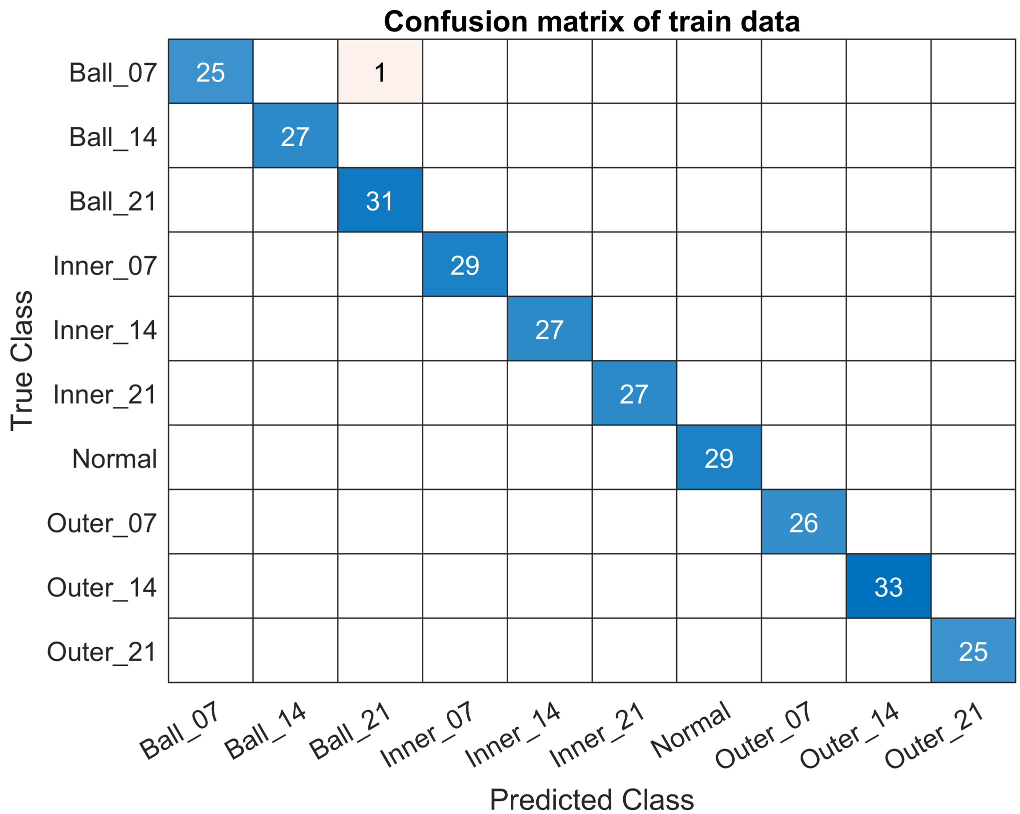


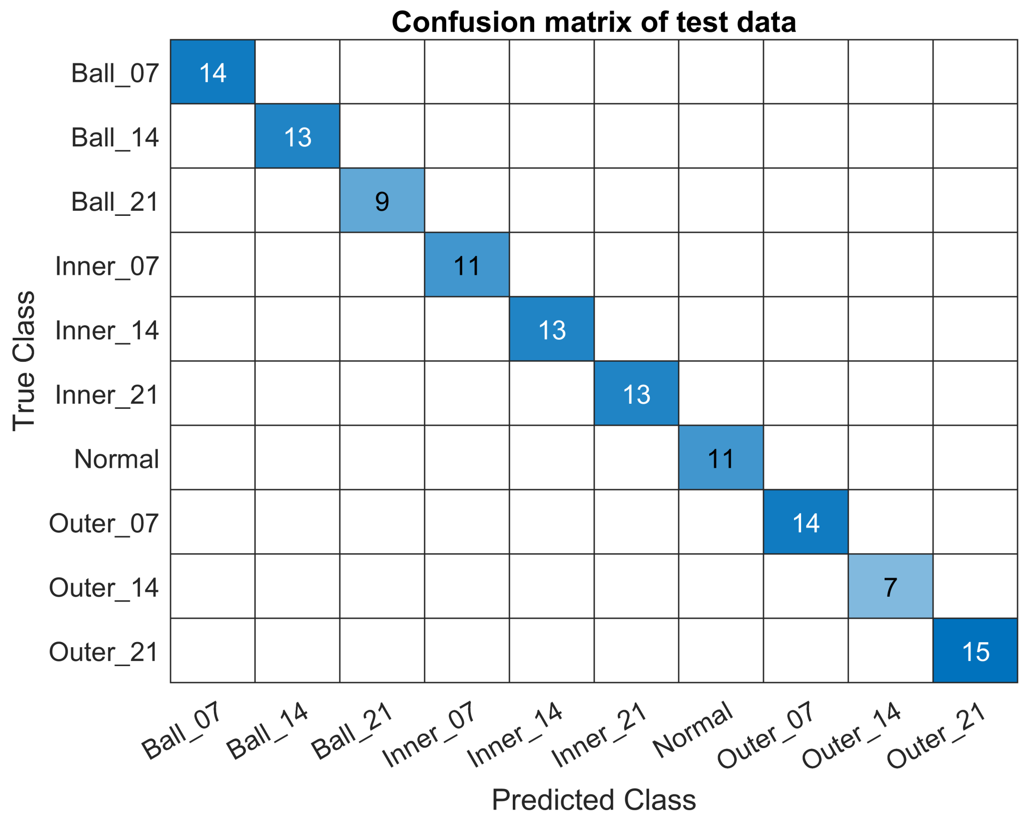


Classification : Global pool

1) KNN

```
poolKNNloss = KNN(poolTrain, poolTrainCls, poolTest, poolTestCls);
```

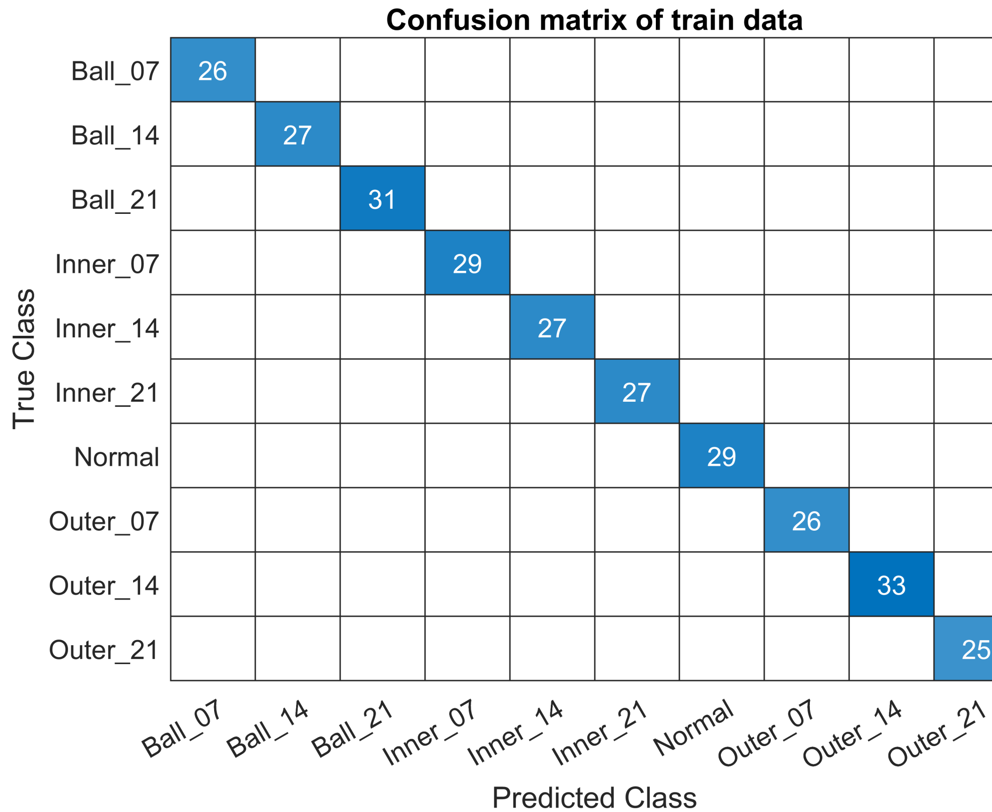


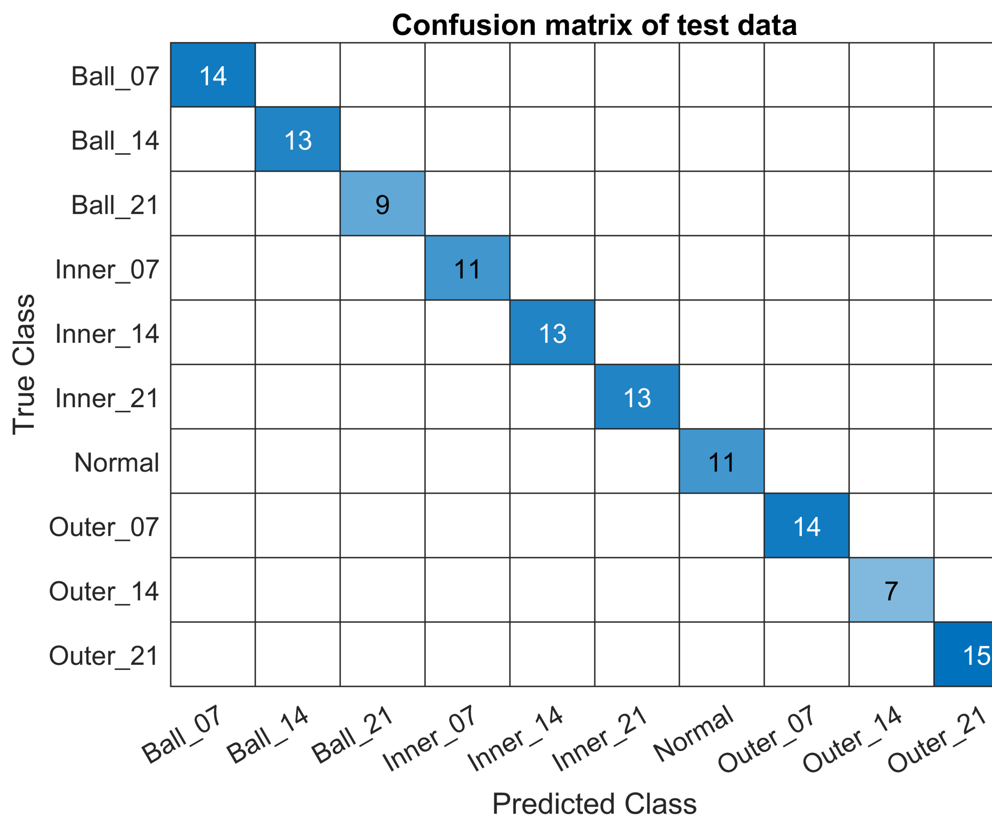


2) SVM

```
poolSVMloss = SVM(poolTrain, poolTrainCls, poolTest, poolTestCls);
```

```
ResubErr_SVM = 0
cvErr_SVM = 0.0036
```

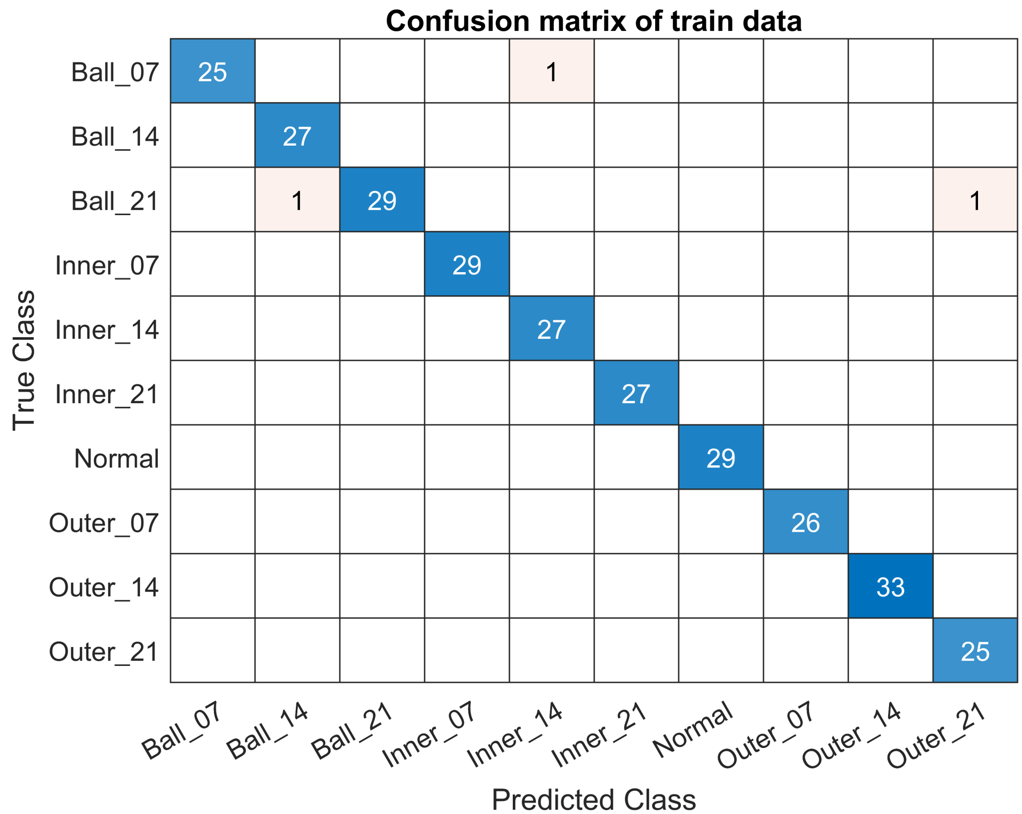


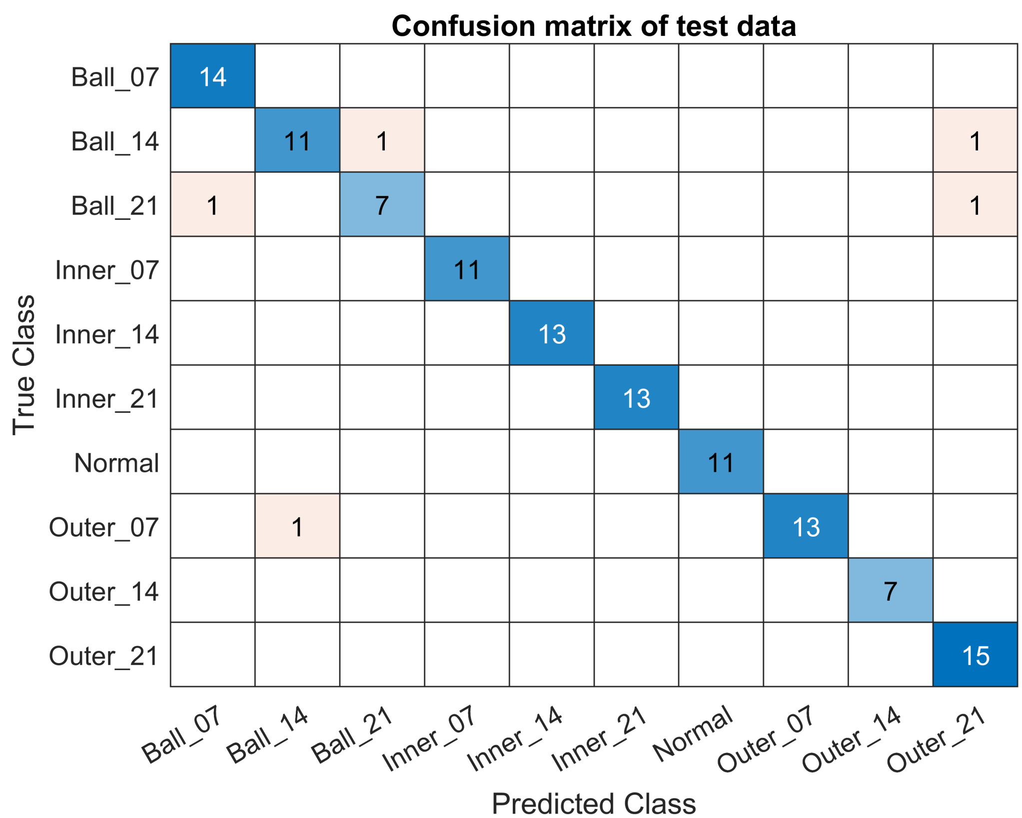


3) Deicision tree

```
poolTREEloss = decisionTree(poolTrain, poolTrainCls, poolTest, poolTestCls);
```

```
ResubErr_Tree = 0.0107
cvErrTree = 0.0964
```





EX2. Feature reduction

- Feature reduction in global pool
- Principal componene analysis, Forward selection

PCA

```
[coeff, scores_train, ~, ~, explained, pcaCenter] = pca(table2array(poolTrain));
```

```
Warning: Columns of X are linearly dependent to within machine precision.
Using only the first 68 components to compute TSQUARED.
```

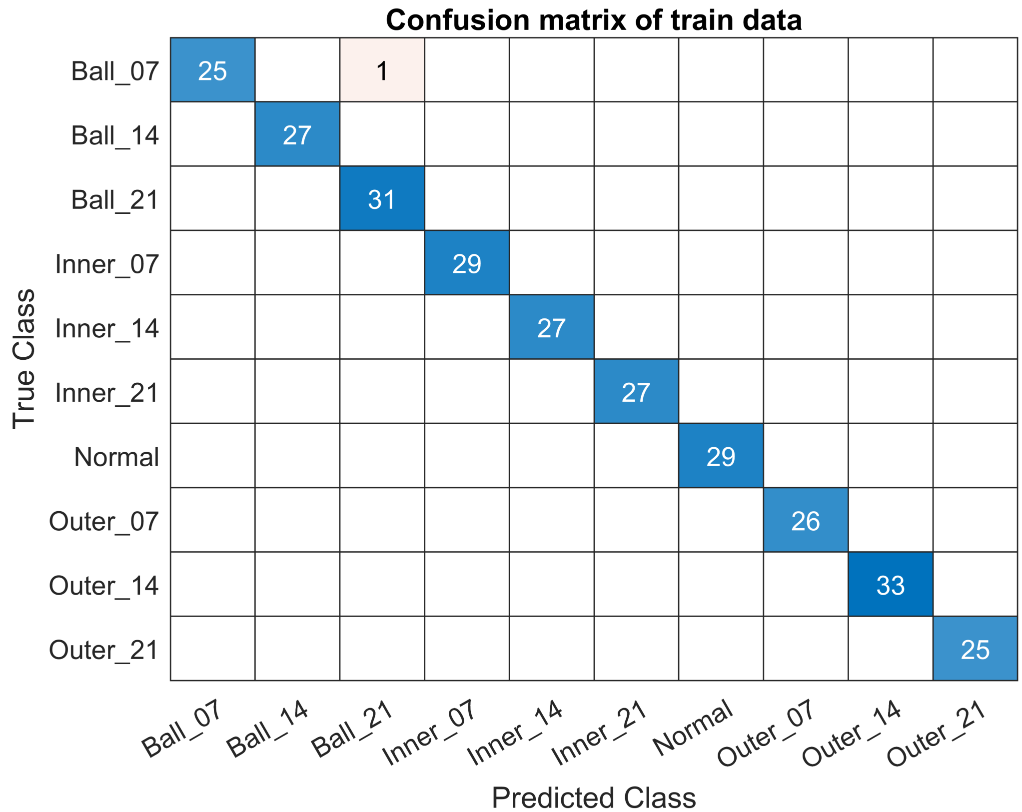
```
explain_standard = 0.95;
num = find(cumsum(explained)/sum(explained) >= explain_standard, 1)
```

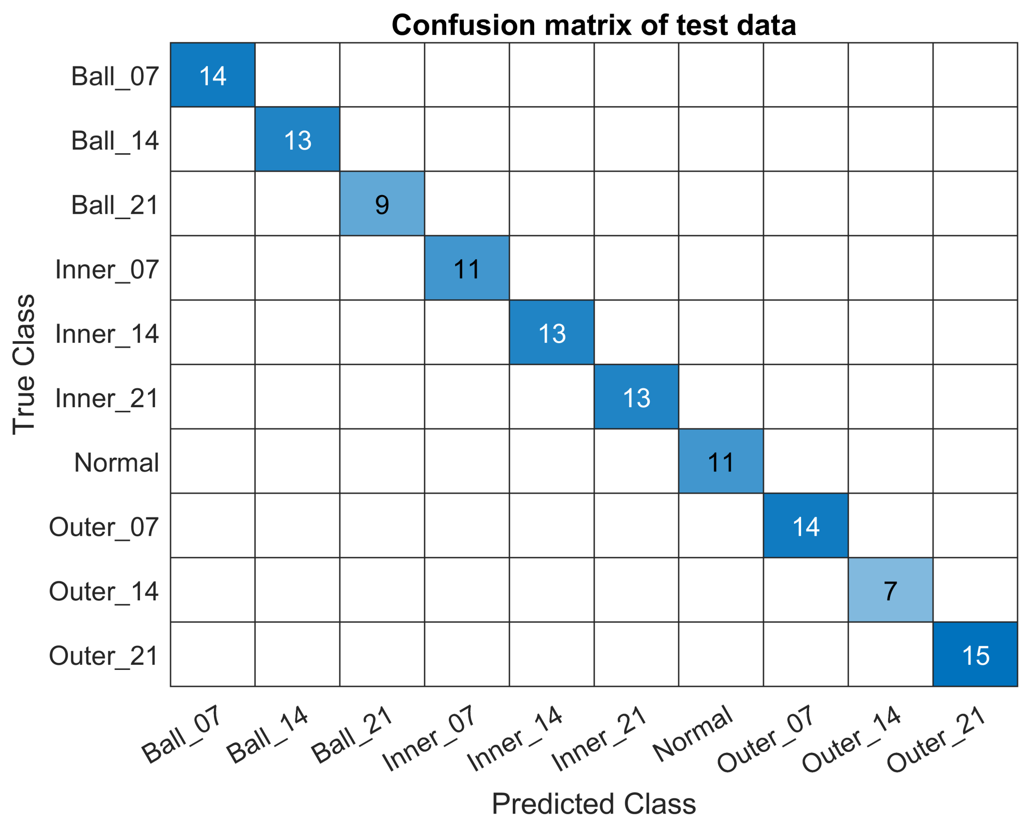
```
num = 14
```

```
coeff = coeff(:,1:num);
scores_train = scores_train(:,1:num);

[n,p] = size(poolTrain);
meanX = mean(table2array(poolTrain),1);

% Xfit: in original coordinate system
Xfit = repmat(meanX,n,1) + scores_train(:,1:num)*coeff(:,1:num)';

[ntest,ptest] = size(poolTest(:,1:end));
mu = repmat(pcaCenter, ntest, 1);
global_test_pca = (table2array(poolTest(:,1:end-1)) - mu)/coeff';
```

- KNN

```
PCA_KNN_loss = KNN(scores_train, poolTrainCls, global_test_pca, poolTestCls);
```

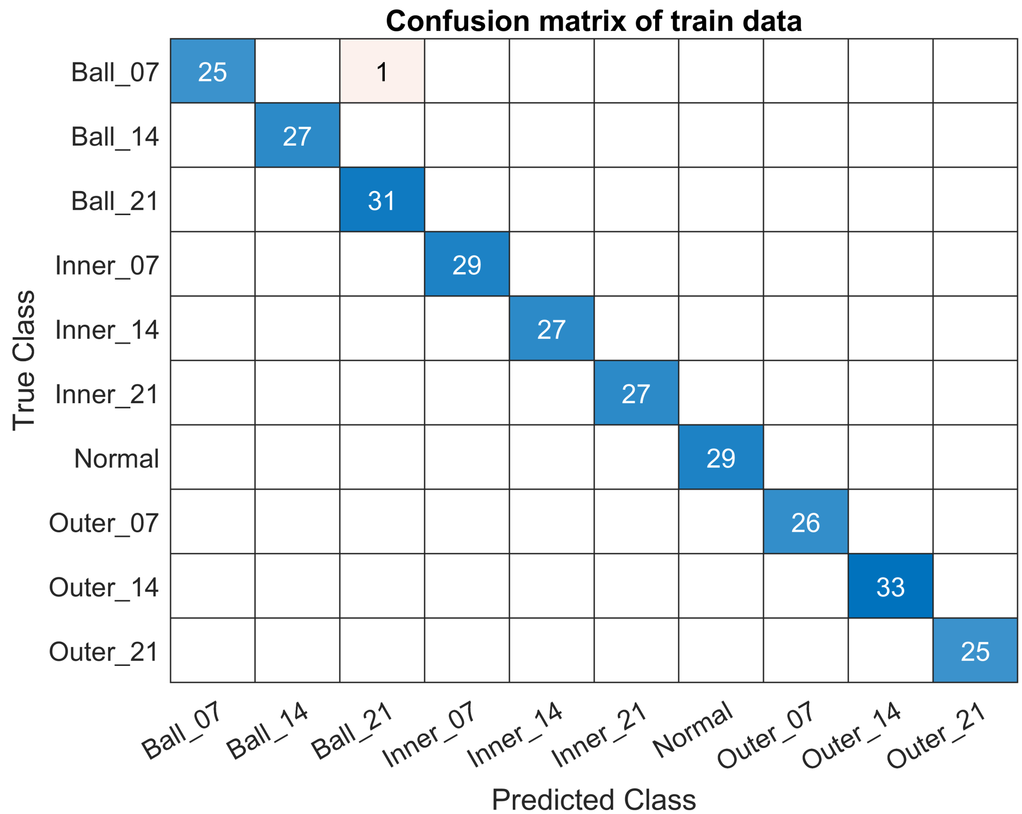

Confusion matrix of train data
True Class
Predicted Class
Ball_07
Ball_14
Ball_21
Inner_07
Inner_14
Inner_21
Normal
Outer_07
Outer_14
Outer_21
25
1
27
31
29
27
27
29
26
33
25

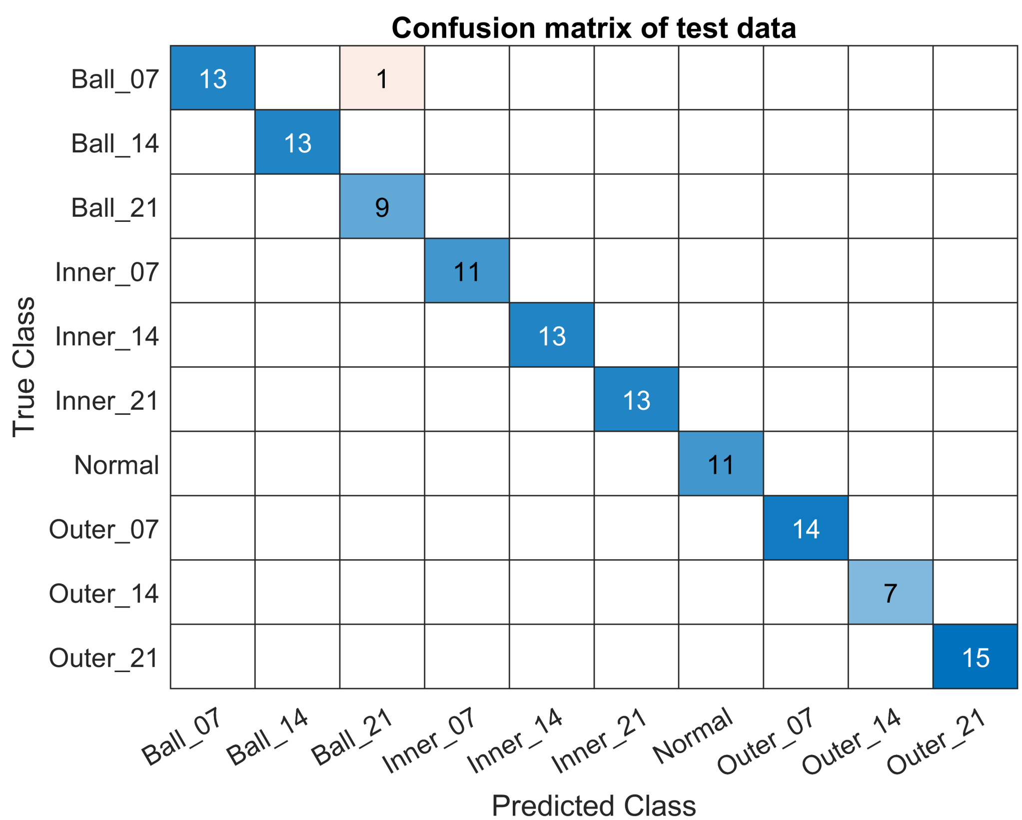

Confusion matrix of test data
True Class
Predicted Class
Ball_07
Ball_14
Ball_21
Inner_07
Inner_14
Inner_21
Normal
Outer_07
Outer_14
Outer_21
14
13
9
11
13
13
11
14
7
15

- SVM

```
PCA_SVM_loss = SVM(scores_train, poolTrainCls, global_test_pca, poolTestCls);
```

```
ResubErr_SVM = 0.0036
cvErr_SVM = 0.0107
```

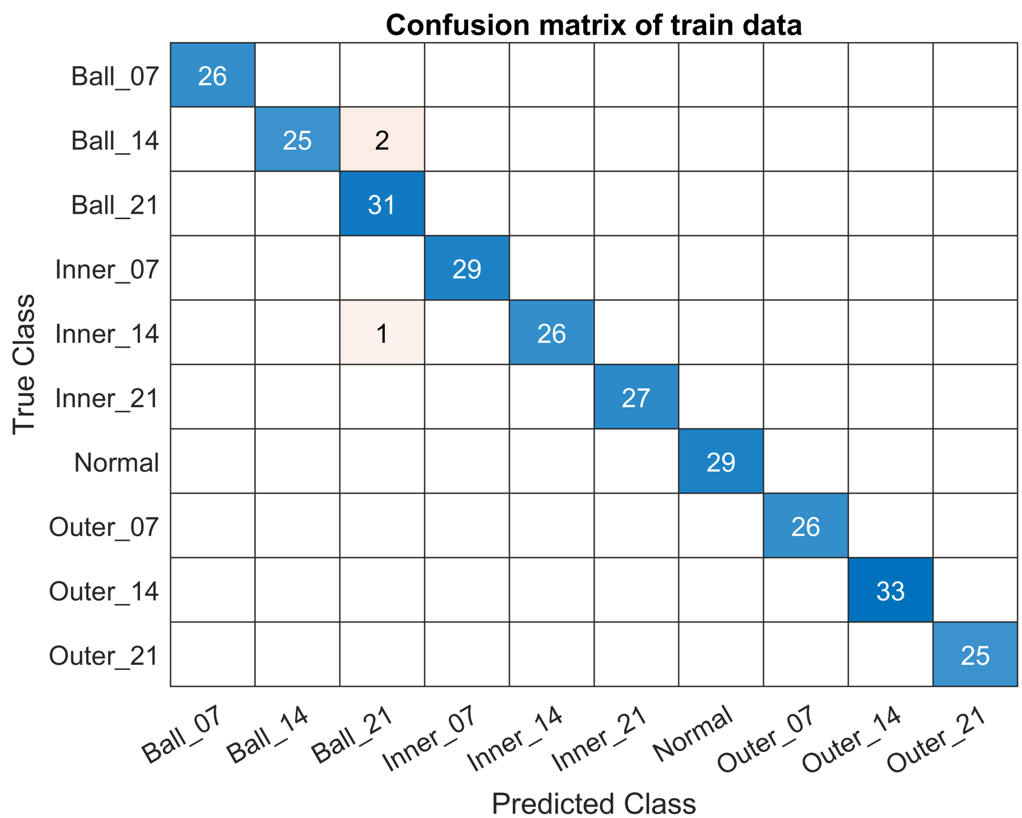


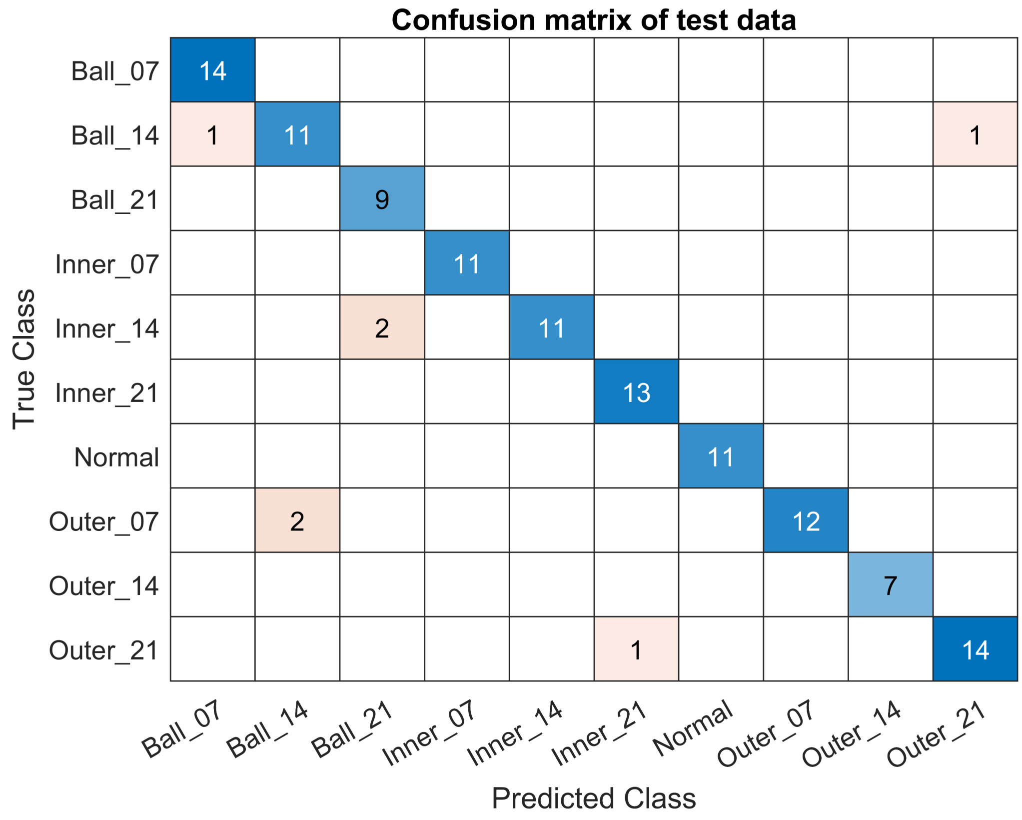


- Decision Tree

```
PCA_Tree_loss = decisionTree(scores_train, poolTrainCls, global_test_pca, poolTestCls);
```

```
ResubErr_Tree = 0.0107
cvErrTree = 0.0964
```





Forward selection

```
rng(0)
Y = height(poolTrain);
cv = cvpartition(Y,'KFold',3);

lossfun = 'mincost';
opts = statset('Display','iter');

k =1;
fun = @(XT,yT,Xt,yt)loss(fitcknn(XT,yT, 'NumNeighbors', k, 'Standardize', 1),Xt,yt, 'Lossfun',

rng(0)

dir = 'forward';
[inmodel, history] = sequentialfs(fun, table2array(poolTrain), poolTrainCls, 'cv', cv, 'options
```

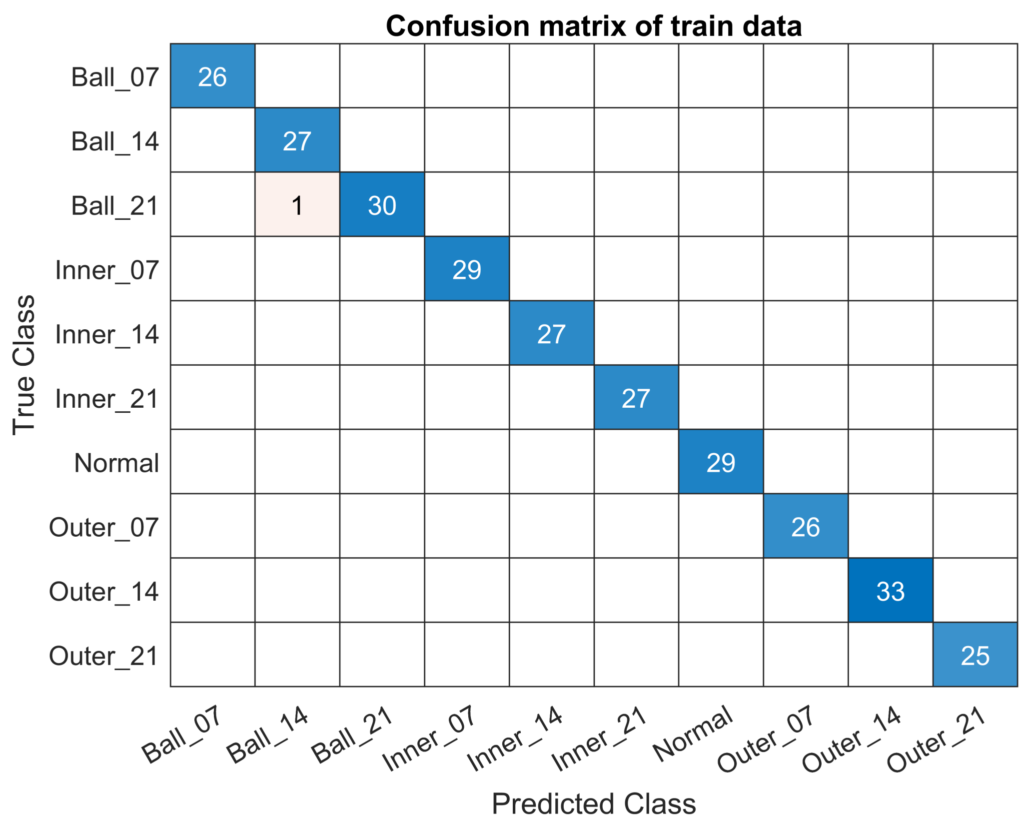
```
Start forward sequential feature selection:
Initial columns included:  none
Columns that can not be included:  none
Step 1, added column 16, criterion value 0.00241256
Step 2, added column 69, criterion value 0.000592119
Step 3, added column 31, criterion value 0
Final columns included:  16 31 69
inmodel = 1×69 logical array
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0⋯
history = struct with fields:
```

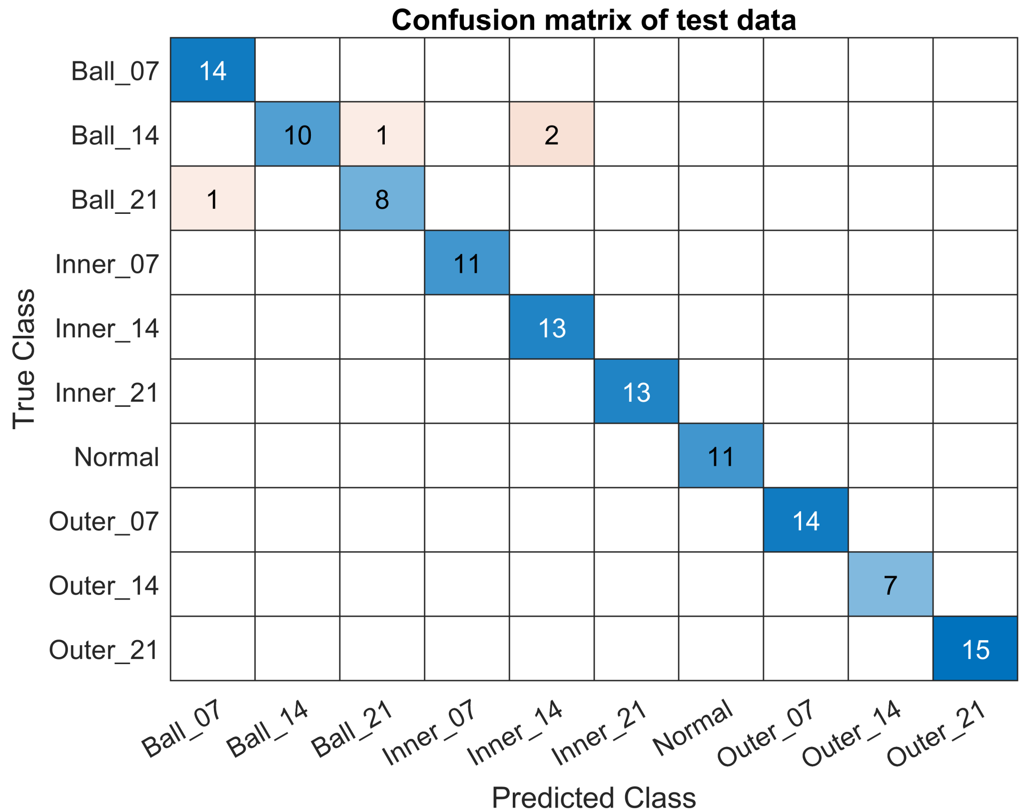
```
     In: [3×69 logical]
   Crit: [0.0024 5.9212e-04 0]
```

```
select = find(inmodel);
global_Train_select = poolTrain(:,select);
global_Test_select = poolTest(:,select);
```

- KNN

```
SFS_KNN_loss = KNN(global_Train_select, poolTrainCls, global_Test_select, poolTestCls)
```



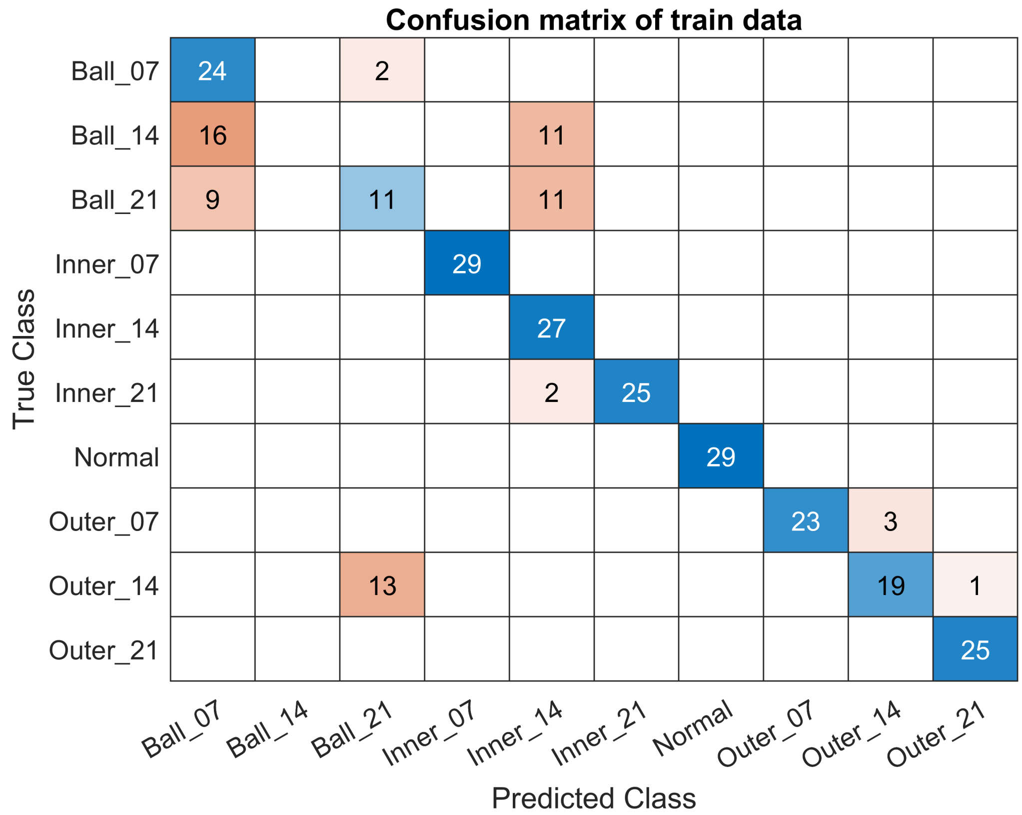


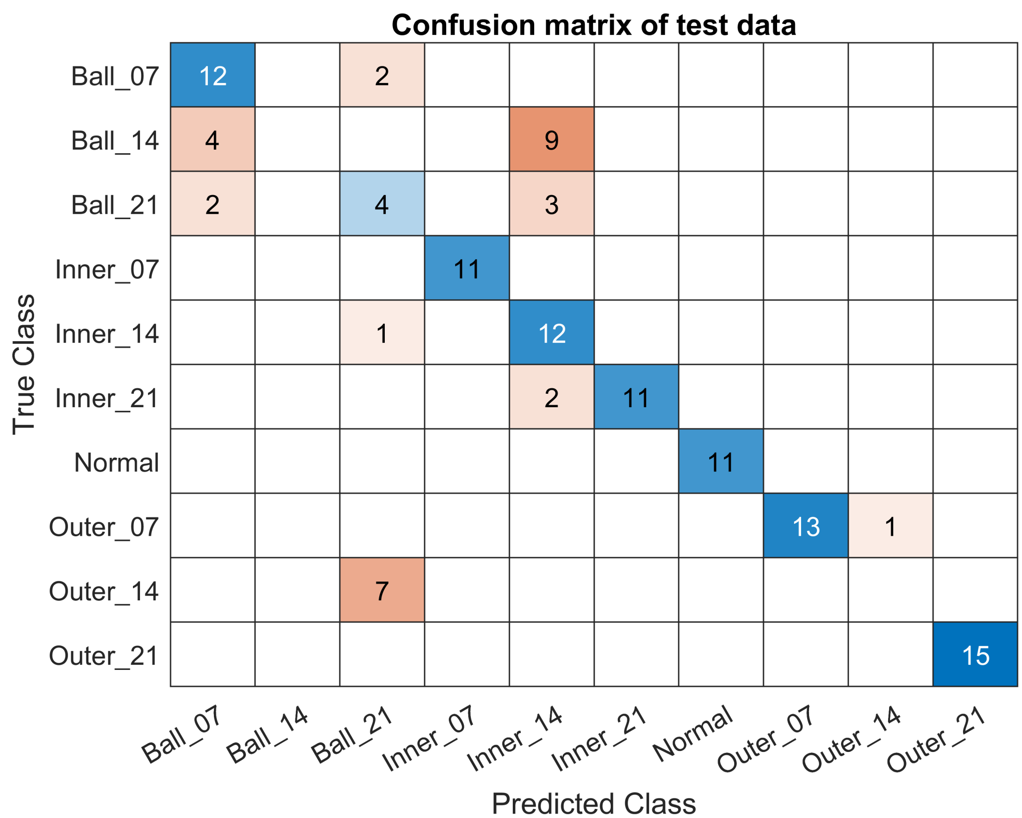

```
SFS_KNN_loss = 0.0346
```

- SVM

```
SFS_SVM_loss = SVM(global_Train_select, poolTrainCls, global_Test_select, poolTestCls)
```

```
ResubErr_SVM = 0.2429
cvErr_SVM = 0.3250
```



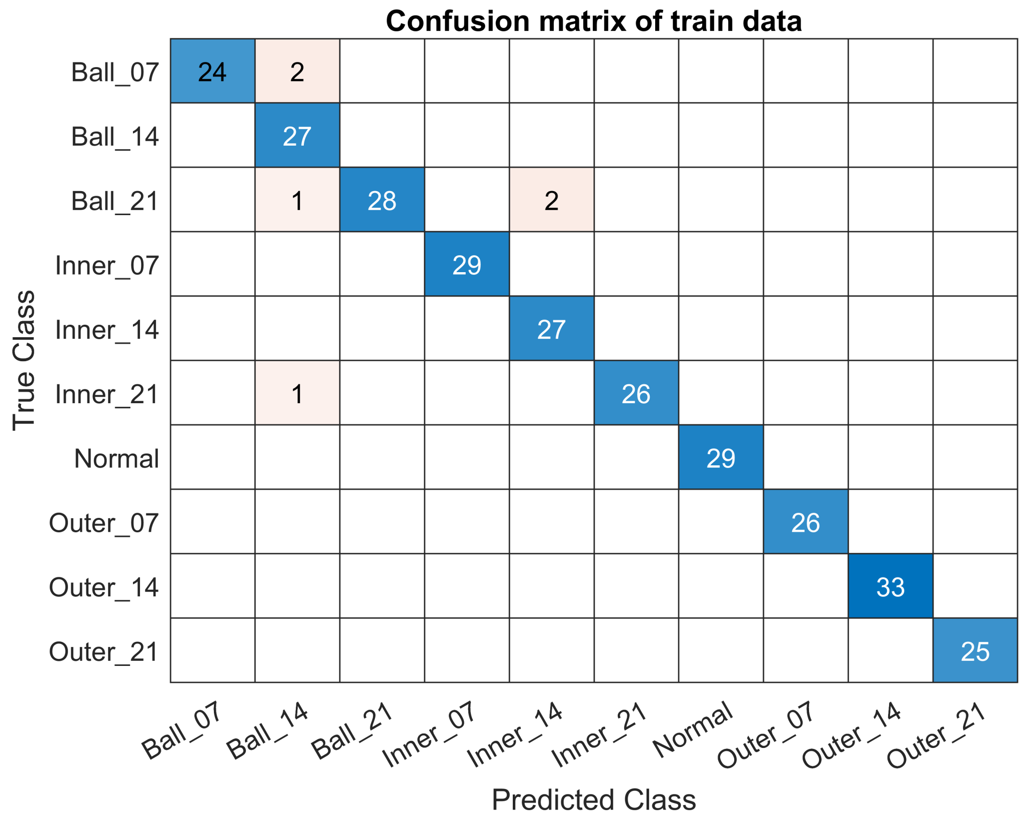


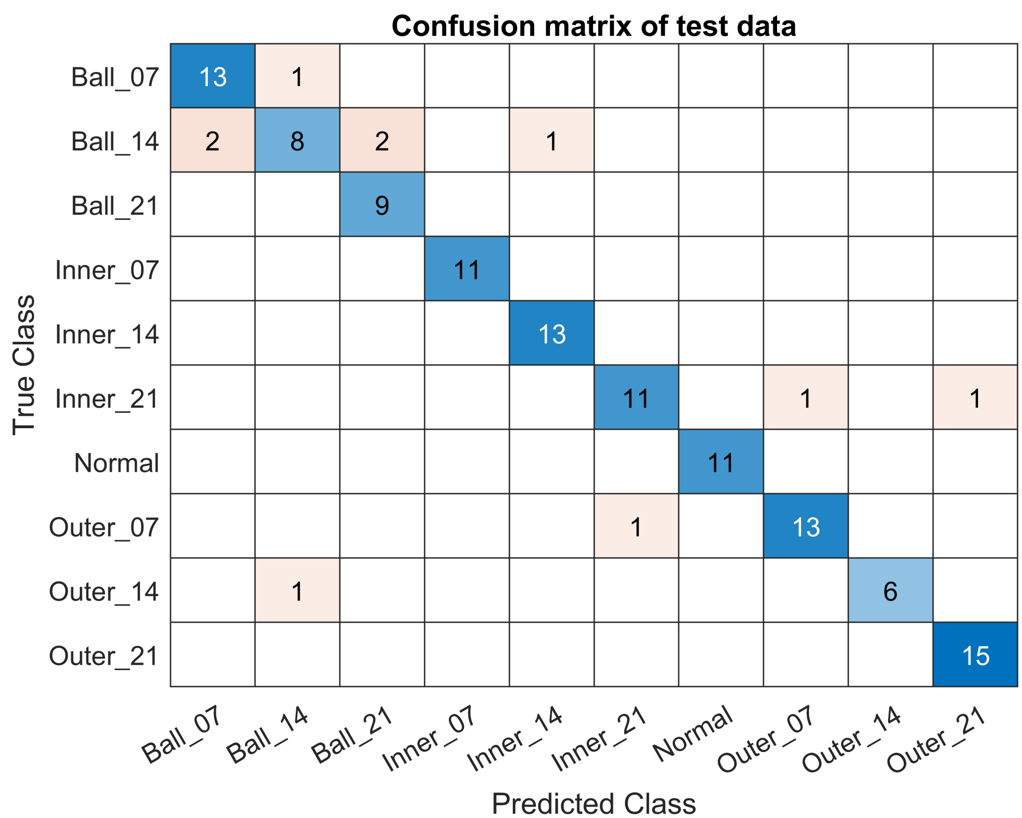

```
SFS_SVM_loss = 0.3179
```

- Decision tree

```
SFS_Tree_loss = decisionTree(global_Train_select, poolTrainCls, global_Test_select, poolTestCl
```

```
ResubErr_Tree = 0.0214
cvErrTree = 0.0857
```





```
SFS_Tree_loss = 0.0820
```

- Table for comparing accuracy of each model

Compare objects : compare the each result of (without selecting vs selecting)

- Without selection

```
cmpLoss_without = [ stcKNNloss stcSVMloss stcTREEloss   ;
                    envKNNloss envSVMloss envTREEloss   ;
                    waveKNNloss waveSVMloss waveTREEloss;
                    poolKNNloss poolSVMloss poolTREEloss]
```

```
cmpLoss_without = 4×3
    0.1255    0.1457    0.0450
    0.0148    0.0133    0.1321
         0    0.0074    0.0469
         0         0    0.0461
```

```
accuracy = round((1 - cmpLoss_without)*100, 2);

colName = ["KNN [%]", "SVM [%]", "Decision Tree [%]"];
rowName = ["Statistical feature", "Envelop feature", "Wavelet feature", "Global pool"];

withoutTbl = array2table(accuracy, "VariableNames", colName, "rownames", rowName)
```

withoutTbl = 4×3 table

	KNN [%]	SVM [%]	Decision Tree [%]
1 Statistical feature	87.4500	85.4300	95.5000
2 Envelop feature	98.5200	98.6700	86.7900
3 Wavelet feature	100	99.2600	95.3100
4 Global pool	100	100	95.3900

- With selection

```
loss_array_with = [PCA_KNN_loss PCA_SVM_loss PCA_Tree_loss ; ...
                   SFS_KNN_loss SFS_SVM_loss SFS_Tree_loss    ]
```

```
loss_array_with = 2×3
         0    0.0066    0.0489
    0.0346    0.3179    0.0820
```

```
accuracy_array_with = round((1 - loss_array_with) * 100,2);

rowName = ["PCA Pool" , "SFS Pool"];
```

```
accuracy_table_with = array2table(accuracy_array_with, "VariableNames", colName , "rownames", r
```

accuracy_table_with = 2×3 table

	KNN [%]	SVM [%]	Decision Tree [%]
1 PCA Pool	100	99.3400	95.1100
2 SFS Pool	96.5400	68.2100	91.8000

Discussion and analysisss

1) Data augmentation

In machine learning, it is important to divide a large dataset into multiple segments and process them on a segment-by-segment basis to achieve efficient learning. In this lab, the data is a time-series dataset, and the dataset size is large, so it is essential to consider an appropriate data augmentation technique. In this lab, the window sliding technique was applied, dividing a large dataset into multiple segments and implementing this technique by setting the overlap ratio between each segment. The parameters used in the aforementioned window sliding technique are as follows:

- Number of segments to divide the dataset into: 20
- Overlap ratio: 0.2 (ratio of overlap between segments)

By dividing a large dataset into multiple segments, we can better reflect its temporal characteristics and extract better features. For example, applying wavelet transformation on a segment-by-segment basis can extract higher-frequency components of the data more effectively.

2) Feature without selection

Experimental results showed that the KNN model applied to all features without feature selection achieved accuracy rates of 87.45% and 98% for the statistical feature and envelop feature, respectively. Similarly, the soft vector machine and decision tree techniques also demonstrated comparable performance, with KNN exhibiting the best performance. However, decision tree models with complex structures are prone to overfitting, leading to high accuracy for training data but low accuracy for new test data. To address this issue and improve generalization performance, feature reduction techniques such as PCA or limiting the model depth of decision trees can be utilized.

3) Feature with selection

In machine learning, creating models using all available features without selecting the most relevant ones can result in poor predictive performance since the model may include features with poor performance. To avoid this, techniques like Principal Component Analysis (PCA) are used to reduce the number of features and only keep the ones with better performance. This technique allows learning to proceed with fewer features that are above a set threshold and still achieve similar or better performance.

In our experiment, we observed that the performance of the feature pool was relatively low, except for the K-Nearest Neighbor (KNN) algorithm. However, by performing dimension reduction using PCA and selecting only the most informative features, we were able to achieve high accuracy with a small number of features. This approach is necessary because creating models using all features without PCA can lead to the Curse of Dimensionality, where high-dimensional data becomes more complex and sparse, making it difficult for the model to find patterns and generalize well to new data.

Therefore, applying PCA and selecting only the most informative features is an effective technique to reduce computational cost while improving the efficiency and accuracy of machine learning models.