Notebook

November 9, 2025

[1]:
```
import numpy as np
import pandas as pd

import seaborn as sns
from seaborn import heatmap

import scipy.stats as stats

import matplotlib.pyplot as plt

df = pd.read_csv('data/steel-plates-fault.csv', sep=',')
df.rename(columns={'V1': 'X_Minimum'}, inplace=True)
df.rename(columns={'V2': 'X_Maximum'}, inplace=True)
df.rename(columns={'V3': 'Y_Minimum'}, inplace=True)
df.rename(columns={'V4': 'Y_Maximum'}, inplace=True)
df.rename(columns={'V5': 'Pixels_Areas'}, inplace=True)
df.rename(columns={'V6': 'X_Perimeter'}, inplace=True)
df.rename(columns={'V7': 'Y_Perimeter'}, inplace=True)
df.rename(columns={'V8': 'Sum_of_Luminosity'}, inplace=True)
df.rename(columns={'V9': 'Minimum_of_Luminosity'}, inplace=True)
df.rename(columns={'V10': 'Maximum_of_Luminosity'}, inplace=True)
df.rename(columns={'V11': 'Length_of_Conveyer'}, inplace=True)
df.rename(columns={'V12': 'TypesOfSteel_A300'}, inplace=True)
df.rename(columns={'V13': 'TypesOfSteel_A400'}, inplace=True)
df.rename(columns={'V14': 'Steel_Plate_Thickness'}, inplace=True)
df.rename(columns={'V15': 'Edges_Index'}, inplace=True)
df.rename(columns={'V16': 'Empty_Index'}, inplace=True)
df.rename(columns={'V17': 'Square_Index'}, inplace=True)
df.rename(columns={'V18': 'Outside_X_Index'}, inplace=True)
df.rename(columns={'V19': 'Edges_X_Index'}, inplace=True)
df.rename(columns={'V20': 'Edges_Y_Index'}, inplace=True)
df.rename(columns={'V21': 'Outside_Global_Index'}, inplace=True)
df.rename(columns={'V22': 'LogOfAreas'}, inplace=True)
df.rename(columns={'V23': 'Log_X_Index'}, inplace=True)
df.rename(columns={'V24': 'Log_Y_Index'}, inplace=True)
df.rename(columns={'V25': 'Orientation_Index'}, inplace=True)
df.rename(columns={'V26': 'Luminosity_Index'}, inplace=True)
```

```
df.rename(columns={'V27': 'SigmoidOfAreas'}, inplace=True)
df.rename(columns={'V28': 'Pastry'}, inplace=True)
df.rename(columns={'V29': 'Z_Scratch'}, inplace=True)
df.rename(columns={'V30': 'K_Scratch'}, inplace=True)
df.rename(columns={'V31': 'Stains'}, inplace=True)
df.rename(columns={'V32': 'Dirtiness'}, inplace=True)
df.rename(columns={'V33': 'Bumps'}, inplace=True)
df.rename(columns={'Class': 'Class'}, inplace=True) # Other_Faults
df
```

[1]:

	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	Pixels_Areas	X_Perimeter	\
0	42	50	270900	270944	267	17	
1	645	651	2538079	2538108	108	10	
2	829	835	1553913	1553931	71	8	
3	853	860	369370	369415	176	13	
4	1289	1306	498078	498335	2409	60	
…	…	…	…	…	…	…	
1936	249	277	325780	325796	273	54	
1937	144	175	340581	340598	287	44	
1938	145	174	386779	386794	292	40	
1939	137	170	422497	422528	419	97	
1940	1261	1281	87951	87967	103	26	

	Y_Perimeter	Sum_of_Luminosity	Minimum_of_Luminosity	\
0	44	24220	76	
1	30	11397	84	
2	19	7972	99	
3	45	18996	99	
4	260	246930	37	
…	…	…	…	
1936	22	35033	119	
1937	24	34599	112	
1938	22	37572	120	
1939	47	52715	117	
1940	22	11682	101	

	Maximum_of_Luminosity	…	Orientation_Index	Luminosity_Index	\
0	108	…	0.8182	-0.2913	
1	123	…	0.7931	-0.1756	
2	125	…	0.6667	-0.1228	
3	126	…	0.8444	-0.1568	
4	126	…	0.9338	-0.1992	
…	…	…	…	…	
1936	141	…	-0.4286	0.0026	
1937	133	…	-0.4516	-0.0582	
1938	140	…	-0.4828	0.0052	
1939	140	…	-0.0606	-0.0171	

```
1940                   133  …            -0.2000           -0.1139

      SigmoidOfAreas  Pastry  Z_Scratch  K_Scratch  Stains  Dirtiness  Bumps  \
0             0.5822       1          0          0       0          0      0
1             0.2984       1          0          0       0          0      0
2             0.2150       1          0          0       0          0      0
3             0.5212       1          0          0       0          0      0
4             1.0000       1          0          0       0          0      0
…                …      …          …          …       …          …      …
1936          0.7254       0          0          0       0          0      0
1937          0.8173       0          0          0       0          0      0
1938          0.7079       0          0          0       0          0      0
1939          0.9919       0          0          0       0          0      0
1940          0.5296       0          0          0       0          0      0

      Class
0         1
1         1
2         1
3         1
4         1
…     …
1936      2
1937      2
1938      2
1939      2
1940      2

[1941 rows x 34 columns]
```

[2]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1941 entries, 0 to 1940
Data columns (total 34 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   X_Minimum              1941 non-null   int64
 1   X_Maximum              1941 non-null   int64
 2   Y_Minimum              1941 non-null   int64
 3   Y_Maximum              1941 non-null   int64
 4   Pixels_Areas           1941 non-null   int64
 5   X_Perimeter            1941 non-null   int64
 6   Y_Perimeter            1941 non-null   int64
 7   Sum_of_Luminosity      1941 non-null   int64
 8   Minimum_of_Luminosity  1941 non-null   int64
 9   Maximum_of_Luminosity  1941 non-null   int64
 10  Length_of_Conveyer     1941 non-null   int64
```

```
 11  TypesOfSteel_A300      1941 non-null   int64
 12  TypesOfSteel_A400      1941 non-null   int64
 13  Steel_Plate_Thickness  1941 non-null   int64
 14  Edges_Index            1941 non-null   float64
 15  Empty_Index            1941 non-null   float64
 16  Square_Index           1941 non-null   float64
 17  Outside_X_Index        1941 non-null   float64
 18  Edges_X_Index          1941 non-null   float64
 19  Edges_Y_Index          1941 non-null   float64
 20  Outside_Global_Index   1941 non-null   float64
 21  LogOfAreas             1941 non-null   float64
 22  Log_X_Index            1941 non-null   float64
 23  Log_Y_Index            1941 non-null   float64
 24  Orientation_Index      1941 non-null   float64
 25  Luminosity_Index       1941 non-null   float64
 26  SigmoidOfAreas         1941 non-null   float64
 27  Pastry                 1941 non-null   int64
 28  Z_Scratch              1941 non-null   int64
 29  K_Scratch              1941 non-null   int64
 30  Stains                 1941 non-null   int64
 31  Dirtiness              1941 non-null   int64
 32  Bumps                  1941 non-null   int64
 33  Class                  1941 non-null   int64
dtypes: float64(13), int64(21)
memory usage: 515.7 KB
```

[3]:
```
print("Duplicates (rows):", df.duplicated().sum())
```

```
Duplicates (rows): 0
```

[4]:
```
df.describe()
```

[4]:

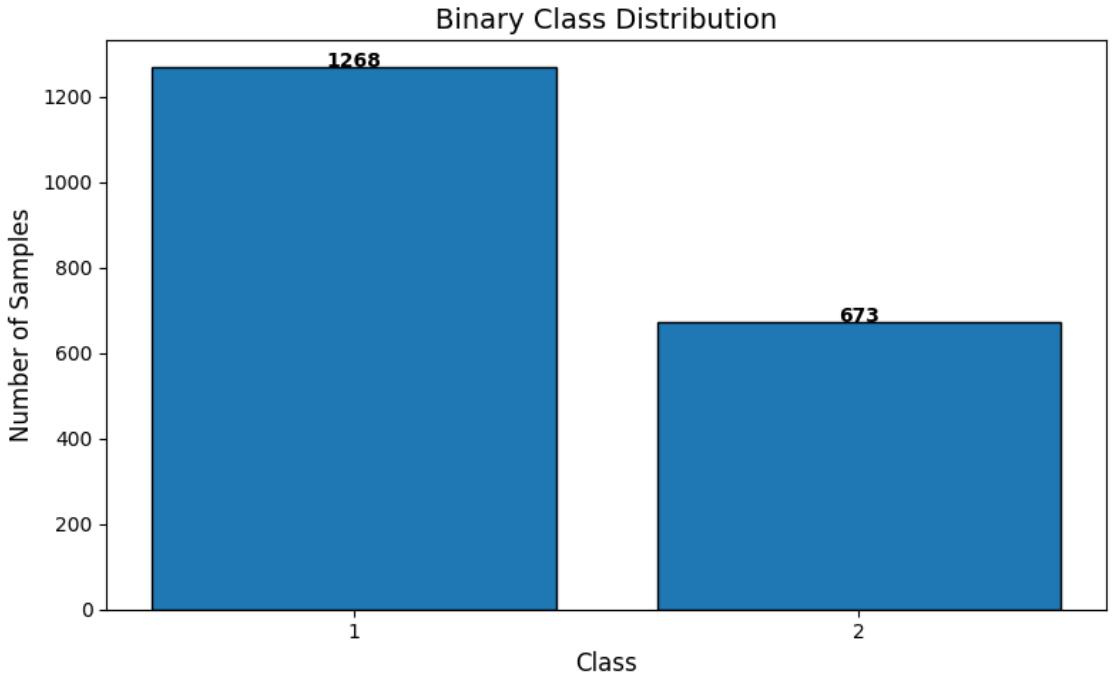
	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	Pixels_Areas	\
count	1941.000000	1941.000000	1.941000e+03	1.941000e+03	1941.000000	
mean	571.136012	617.964451	1.650685e+06	1.650739e+06	1893.878413	
std	520.690671	497.627410	1.774578e+06	1.774590e+06	5168.459560	
min	0.000000	4.000000	6.712000e+03	6.724000e+03	2.000000	
25%	51.000000	192.000000	4.712530e+05	4.712810e+05	84.000000	
50%	435.000000	467.000000	1.204128e+06	1.204136e+06	174.000000	
75%	1053.000000	1072.000000	2.183073e+06	2.183084e+06	822.000000	
max	1705.000000	1713.000000	1.298766e+07	1.298769e+07	152655.000000	

	X_Perimeter	Y_Perimeter	Sum_of_Luminosity	Minimum_of_Luminosity	\
count	1941.000000	1941.000000	1.941000e+03	1941.000000	
mean	111.855229	82.965997	2.063121e+05	84.548686	
std	301.209187	426.482879	5.122936e+05	32.134276	
min	2.000000	1.000000	2.500000e+02	0.000000	
25%	15.000000	13.000000	9.522000e+03	63.000000	

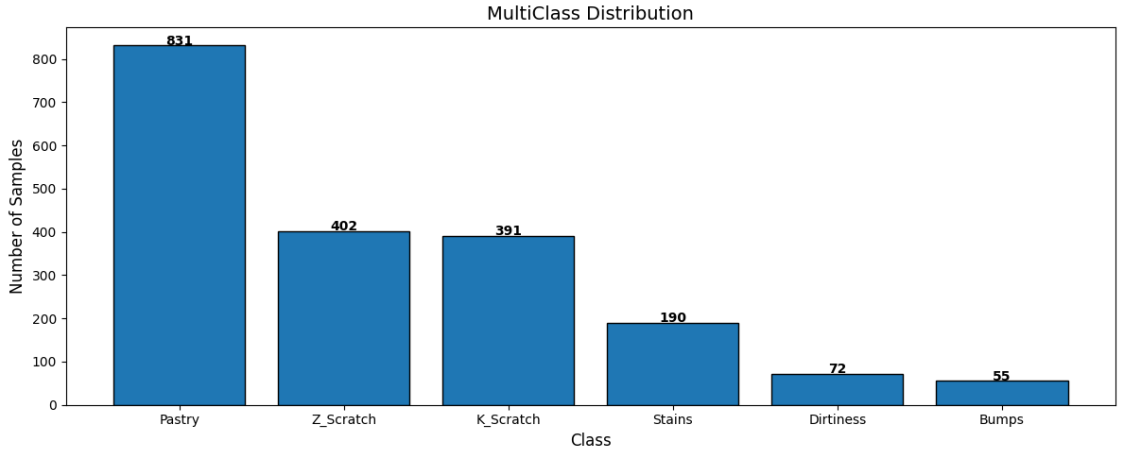
```
50%       26.000000     25.000000       1.920200e+04              90.000000
75%       84.000000     83.000000       8.301100e+04             106.000000
max    10449.000000  18152.000000       1.159141e+07             203.000000

       Maximum_of_Luminosity  …  Orientation_Index  Luminosity_Index  \
count            1941.000000  …        1941.000000       1941.000000
mean              130.193715  …           0.083288         -0.131305
std                18.690992  …           0.500868          0.148767
min                37.000000  …          -0.991000         -0.998900
25%               124.000000  …          -0.333300         -0.195000
50%               127.000000  …           0.095200         -0.133000
75%               140.000000  …           0.511600         -0.066600
max               253.000000  …           0.991700          0.642100

       SigmoidOfAreas       Pastry    Z_Scratch    K_Scratch       Stains  \
count     1941.000000  1941.000000  1941.000000  1941.000000  1941.000000
mean         0.585420     0.081401     0.097888     0.201443     0.037094
std          0.339452     0.273521     0.297239     0.401181     0.189042
min          0.119000     0.000000     0.000000     0.000000     0.000000
25%          0.248200     0.000000     0.000000     0.000000     0.000000
50%          0.506300     0.000000     0.000000     0.000000     0.000000
75%          0.999800     0.000000     0.000000     0.000000     0.000000
max          1.000000     1.000000     1.000000     1.000000     1.000000

         Dirtiness        Bumps        Class
count  1941.000000  1941.000000  1941.000000
mean      0.028336     0.207110     1.346728
std       0.165973     0.405339     0.476051
min       0.000000     0.000000     1.000000
25%       0.000000     0.000000     1.000000
50%       0.000000     0.000000     1.000000
75%       0.000000     0.000000     2.000000
max       1.000000     1.000000     2.000000

[8 rows x 34 columns]
```

[5]:
```python
import matplotlib.pyplot as plt

counts = df["Class"].value_counts()

plt.figure(figsize=(8, 5))
plt.bar(counts.index.astype(str), counts.values, edgecolor="black")
plt.title("Binary Class Distribution", fontsize=14)
plt.xlabel("Class", fontsize=12)
plt.ylabel("Number of Samples", fontsize=12)
for i, v in enumerate(counts.values):
    plt.text(i, v + 0.5, str(v), ha='center', fontweight='bold')
```

```
plt.tight_layout()
plt.show()
```



[6]:
```
import matplotlib.pyplot as plt

class_names = "Pastry Z_Scratch K_Scratch Stains Dirtiness Bumps".split(" ")
counts = df[class_names].dot([i for i in range(6)]).value_counts()

plt.figure(figsize=(12, 5))
plt.bar(class_names, counts.values, edgecolor="black")
plt.title("MultiClass Distribution", fontsize=14)
plt.xlabel("Class", fontsize=12)
plt.ylabel("Number of Samples", fontsize=12)

for i, v in enumerate(counts.values):
    plt.text(i, v + 0.5, str(v), ha='center', fontweight='bold')
plt.tight_layout()
plt.show()
```



[7]:
```
"Pastry Z_Scratch K_Scratch Stains Dirtiness Bumps".split(" ")
```

[7]:
```
['Pastry', 'Z_Scratch', 'K_Scratch', 'Stains', 'Dirtiness', 'Bumps']
```

[8]:
```
num = df.select_dtypes(include='number')
corr_matrix = num.corr(method='pearson')
corr_matrix
```

[8]:

	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	\
X_Minimum	1.000000	0.988314	0.041821	0.041807	
X_Maximum	0.988314	1.000000	0.052147	0.052135	
Y_Minimum	0.041821	0.052147	1.000000	1.000000	
Y_Maximum	0.041807	0.052135	1.000000	1.000000	
Pixels_Areas	-0.307322	-0.225399	0.017670	0.017840	
X_Perimeter	-0.258937	-0.186326	0.023843	0.024038	
Y_Perimeter	-0.118757	-0.090138	0.024150	0.024380	
Sum_of_Luminosity	-0.339045	-0.247052	0.007362	0.007499	
Minimum_of_Luminosity	0.237637	0.168649	-0.065703	-0.065733	
Maximum_of_Luminosity	-0.075554	-0.062392	-0.067785	-0.067776	
Length_of_Conveyer	0.316662	0.299390	-0.049211	-0.049219	
TypesOfSteel_A300	0.144319	0.112009	0.075164	0.075151	
TypesOfSteel_A400	-0.144319	-0.112009	-0.075164	-0.075151	
Steel_Plate_Thickness	0.136625	0.106119	-0.207640	-0.207644	
Edges_Index	0.278075	0.242846	0.021314	0.021300	
Empty_Index	-0.198461	-0.152680	-0.043117	-0.043085	
Square_Index	0.063658	0.048575	-0.006135	-0.006152	
Outside_X_Index	-0.361160	-0.214930	0.054165	0.054185	
Edges_X_Index	0.154778	0.149259	0.066085	0.066051	
Edges_Y_Index	0.367907	0.271915	-0.036543	-0.036549	
Outside_Global_Index	0.147282	0.099253	-0.062911	-0.062901	
LogOfAreas	-0.428553	-0.332169	0.044952	0.044994	

Log_X_Index	-0.437944	-0.324012	0.070406	0.070432
Log_Y_Index	-0.326851	-0.265990	-0.008442	-0.008382
Orientation_Index	0.178585	0.115019	-0.086497	-0.086480
Luminosity_Index	-0.031578	-0.038996	-0.090654	-0.090666
SigmoidOfAreas	-0.355251	-0.286736	0.025257	0.025284
Pastry	0.134956	0.119814	0.036488	0.036488
Z_Scratch	-0.228960	-0.258178	-0.063327	-0.063329
K_Scratch	-0.419264	-0.336084	-0.000420	-0.000397
Stains	0.073740	0.061471	-0.066601	-0.066606
Dirtiness	0.103924	0.096523	0.064262	0.064262
Bumps	0.221296	0.201704	0.126121	0.126110
Class	0.164804	0.145783	-0.084415	-0.084422

	Pixels_Areas	X_Perimeter	Y_Perimeter	\
X_Minimum	-0.307322	-0.258937	-0.118757	
X_Maximum	-0.225399	-0.186326	-0.090138	
Y_Minimum	0.017670	0.023843	0.024150	
Y_Maximum	0.017840	0.024038	0.024380	
Pixels_Areas	1.000000	0.966644	0.827199	
X_Perimeter	0.966644	1.000000	0.912436	
Y_Perimeter	0.827199	0.912436	1.000000	
Sum_of_Luminosity	0.978952	0.912956	0.704876	
Minimum_of_Luminosity	-0.497204	-0.400427	-0.213758	
Maximum_of_Luminosity	0.110063	0.111363	0.061809	
Length_of_Conveyer	-0.155853	-0.134240	-0.063825	
TypesOfSteel_A300	-0.235591	-0.189250	-0.095154	
TypesOfSteel_A400	0.235591	0.189250	0.095154	
Steel_Plate_Thickness	-0.183735	-0.147712	-0.058889	
Edges_Index	-0.275289	-0.227590	-0.111240	
Empty_Index	0.272808	0.306348	0.188825	
Square_Index	0.017865	0.004507	-0.047511	
Outside_X_Index	0.588606	0.517098	0.209160	
Edges_X_Index	-0.294673	-0.293039	-0.195162	
Edges_Y_Index	-0.463571	-0.412100	-0.136723	
Outside_Global_Index	-0.109655	-0.079106	0.013438	
LogOfAreas	0.650234	0.563036	0.294040	
Log_X_Index	0.603072	0.524716	0.228485	
Log_Y_Index	0.578342	0.523472	0.344378	
Orientation_Index	-0.137604	-0.101731	0.031381	
Luminosity_Index	-0.043449	-0.032617	-0.047778	
SigmoidOfAreas	0.422947	0.380605	0.191772	
Pastry	-0.076752	-0.075418	-0.017616	
Z_Scratch	-0.088440	-0.060582	-0.025721	
K_Scratch	0.556846	0.455003	0.203063	
Stains	-0.071182	-0.067547	-0.035743	
Dirtiness	-0.050578	-0.037820	-0.010058	
Bumps	-0.163739	-0.140197	-0.070989	

```
Class                    -0.184632    -0.142903    -0.066801

                      Sum_of_Luminosity  Minimum_of_Luminosity  \
X_Minimum                     -0.339045               0.237637
X_Maximum                     -0.247052               0.168649
Y_Minimum                      0.007362              -0.065703
Y_Maximum                      0.007499              -0.065733
Pixels_Areas                   0.978952              -0.497204
X_Perimeter                    0.912956              -0.400427
Y_Perimeter                    0.704876              -0.213758
Sum_of_Luminosity              1.000000              -0.540566
Minimum_of_Luminosity         -0.540566               1.000000
Maximum_of_Luminosity          0.136515               0.429605
Length_of_Conveyer            -0.169331              -0.023579
TypesOfSteel_A300             -0.263632               0.042048
TypesOfSteel_A400              0.263632              -0.042048
Steel_Plate_Thickness         -0.204812               0.103393
Edges_Index                   -0.301452               0.358915
Empty_Index                    0.293691              -0.044111
Square_Index                   0.049607               0.066748
Outside_X_Index                0.658339              -0.487574
Edges_X_Index                 -0.327728               0.252256
Edges_Y_Index                 -0.529745               0.316610
Outside_Global_Index          -0.121090               0.035462
LogOfAreas                     0.712128              -0.678762
Log_X_Index                    0.667736              -0.567655
Log_Y_Index                    0.618795              -0.588208
Orientation_Index             -0.158483               0.057123
Luminosity_Index              -0.014067               0.669534
SigmoidOfAreas                 0.464248              -0.514797
Pastry                        -0.084307              -0.074697
Z_Scratch                     -0.099592               0.049905
K_Scratch                      0.616950              -0.461000
Stains                        -0.078111               0.183327
Dirtiness                     -0.055272               0.092765
Bumps                         -0.179831               0.078690
Class                         -0.205890               0.228112

                      Maximum_of_Luminosity  …  Orientation_Index  \
X_Minimum                         -0.075554  …           0.178585
X_Maximum                         -0.062392  …           0.115019
Y_Minimum                         -0.067785  …          -0.086497
Y_Maximum                         -0.067776  …          -0.086480
Pixels_Areas                       0.110063  …          -0.137604
X_Perimeter                        0.111363  …          -0.101731
Y_Perimeter                        0.061809  …           0.031381
Sum_of_Luminosity                  0.136515  …          -0.158483
```

Minimum_of_Luminosity	0.429605	…	0.057123
Maximum_of_Luminosity	1.000000	…	-0.169747
Length_of_Conveyer	-0.098009	…	0.120715
TypesOfSteel_A300	-0.216339	…	0.010630
TypesOfSteel_A400	0.216339	…	-0.010630
Steel_Plate_Thickness	-0.128397	…	0.274097
Edges_Index	0.149675	…	0.020548
Empty_Index	0.031425	…	-0.139420
Square_Index	0.065517	…	-0.162034
Outside_X_Index	0.099300	…	-0.440358
Edges_X_Index	0.093522	…	-0.550302
Edges_Y_Index	-0.167441	…	0.658049
Outside_Global_Index	-0.124039	…	0.862670
LogOfAreas	0.007672	…	-0.123898
Log_X_Index	0.092823	…	-0.536629
Log_Y_Index	-0.069522	…	0.316792
Orientation_Index	-0.169747	…	1.000000
Luminosity_Index	0.870160	…	-0.153464
SigmoidOfAreas	-0.039651	…	-0.023978
Pastry	-0.058742	…	0.329385
Z_Scratch	-0.189441	…	0.117501
K_Scratch	0.185897	…	-0.384696
Stains	0.090456	…	-0.136713
Dirtiness	0.022157	…	0.174628
Bumps	-0.047549	…	0.013614
Class	-0.007784	…	0.043389

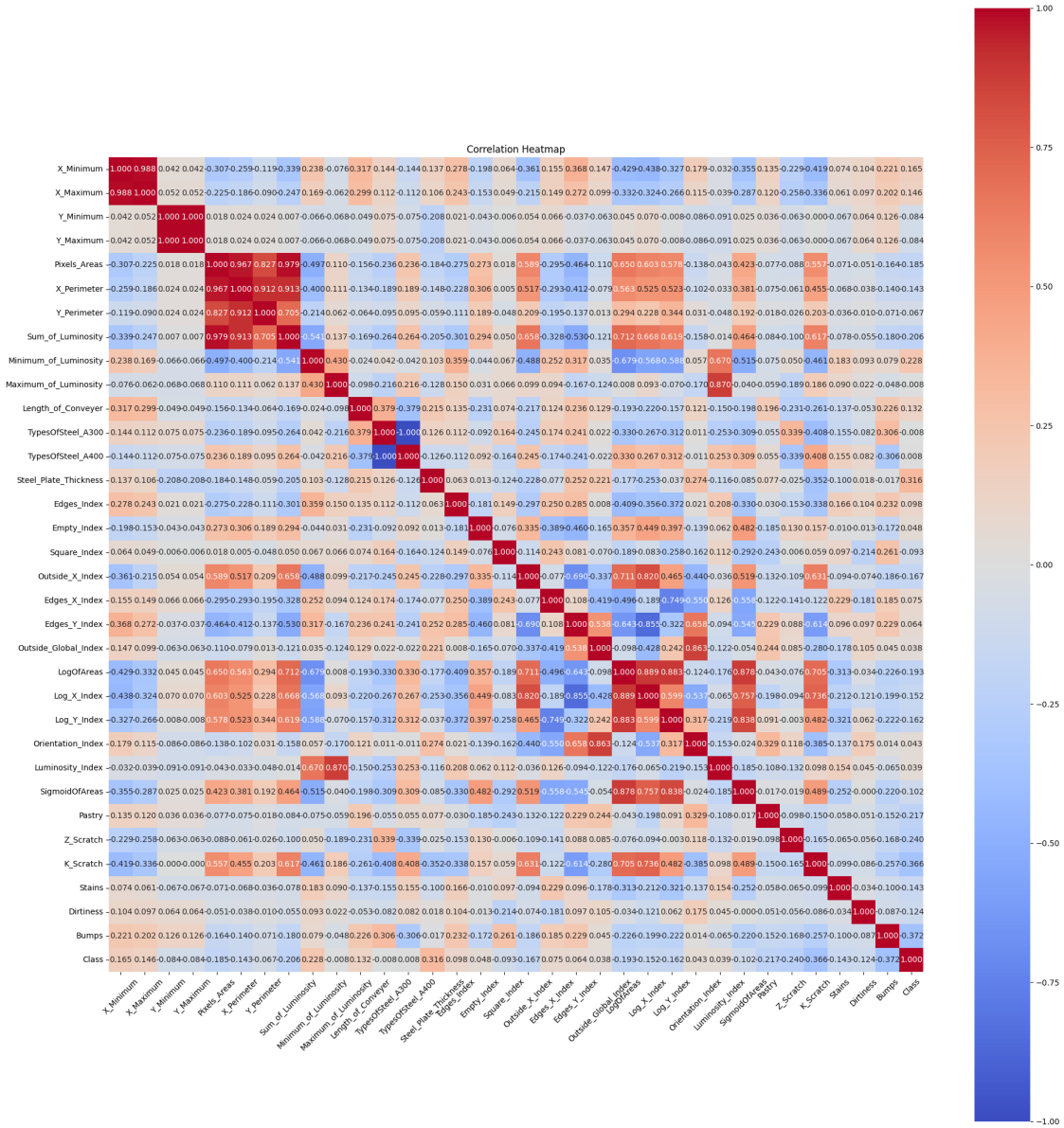
	Luminosity_Index	SigmoidOfAreas	Pastry	Z_Scratch	\
X_Minimum	-0.031578	-0.355251	0.134956	-0.228960	
X_Maximum	-0.038996	-0.286736	0.119814	-0.258178	
Y_Minimum	-0.090654	0.025257	0.036488	-0.063327	
Y_Maximum	-0.090666	0.025284	0.036488	-0.063329	
Pixels_Areas	-0.043449	0.422947	-0.076752	-0.088440	
X_Perimeter	-0.032617	0.380605	-0.075418	-0.060582	
Y_Perimeter	-0.047778	0.191772	-0.017616	-0.025721	
Sum_of_Luminosity	-0.014067	0.464248	-0.084307	-0.099592	
Minimum_of_Luminosity	0.669534	-0.514797	-0.074697	0.049905	
Maximum_of_Luminosity	0.870160	-0.039651	-0.058742	-0.189441	
Length_of_Conveyer	-0.149769	-0.197543	0.196209	-0.230856	
TypesOfSteel_A300	-0.252818	-0.308910	-0.054792	0.339488	
TypesOfSteel_A400	0.252818	0.308910	0.054792	-0.339488	
Steel_Plate_Thickness	-0.116499	-0.085159	0.076579	-0.024876	
Edges_Index	0.207516	-0.330006	-0.029915	-0.152730	
Empty_Index	0.061608	0.481738	-0.184993	0.129672	
Square_Index	0.111977	-0.292251	-0.242923	-0.005543	
Outside_X_Index	-0.035721	0.518910	-0.132081	-0.109354	
Edges_X_Index	0.126460	-0.558426	-0.122428	-0.141291	

Edges_Y_Index	-0.094368	-0.545393	0.229432	0.088045
Outside_Global_Index	-0.122321	-0.053770	0.244320	0.084885
LogOfAreas	-0.175879	0.877768	-0.042526	-0.075564
Log_X_Index	-0.064923	0.757343	-0.198250	-0.094426
Log_Y_Index	-0.219110	0.838188	0.091130	-0.003170
Orientation_Index	-0.153464	-0.023978	0.329385	0.117501
Luminosity_Index	1.000000	-0.184840	-0.108018	-0.131623
SigmoidOfAreas	-0.184840	1.000000	-0.017422	-0.019397
Pastry	-0.108018	-0.017422	1.000000	-0.098059
Z_Scratch	-0.131623	-0.019397	-0.098059	1.000000
K_Scratch	0.098459	0.488878	-0.149512	-0.165446
Stains	0.154319	-0.252488	-0.058427	-0.064654
Dirtiness	0.045295	-0.000462	-0.050835	-0.056253
Bumps	-0.064744	-0.220091	-0.152141	-0.168356
Class	0.039328	-0.102046	-0.216871	-0.239984

	K_Scratch	Stains	Dirtiness	Bumps	Class
X_Minimum	-0.419264	0.073740	0.103924	0.221296	0.164804
X_Maximum	-0.336084	0.061471	0.096523	0.201704	0.145783
Y_Minimum	-0.000420	-0.066601	0.064262	0.126121	-0.084415
Y_Maximum	-0.000397	-0.066606	0.064262	0.126110	-0.084422
Pixels_Areas	0.556846	-0.071182	-0.050578	-0.163739	-0.184632
X_Perimeter	0.455003	-0.067547	-0.037820	-0.140197	-0.142903
Y_Perimeter	0.203063	-0.035743	-0.010058	-0.070989	-0.066801
Sum_of_Luminosity	0.616950	-0.078111	-0.055272	-0.179831	-0.205890
Minimum_of_Luminosity	-0.461000	0.183327	0.092765	0.078690	0.228112
Maximum_of_Luminosity	0.185897	0.090456	0.022157	-0.047549	-0.007784
Length_of_Conveyer	-0.261071	-0.136839	-0.052603	0.225504	0.132091
TypesOfSteel_A300	-0.407730	-0.154796	-0.082489	0.306385	-0.007530
TypesOfSteel_A400	0.407730	0.154796	0.082489	-0.306385	0.007530
Steel_Plate_Thickness	-0.351654	-0.099945	0.017727	-0.016773	0.315671
Edges_Index	-0.337701	0.165732	0.103517	0.232000	0.097698
Empty_Index	0.156711	-0.010243	-0.012514	-0.172147	0.048267
Square_Index	0.059175	0.097310	-0.214369	0.261385	-0.093296
Outside_X_Index	0.631370	-0.093722	-0.074105	-0.185729	-0.166709
Edges_X_Index	-0.121541	0.229406	-0.180588	0.185481	0.074921
Edges_Y_Index	-0.614341	0.096336	0.096862	0.229231	0.063718
Outside_Global_Index	-0.279992	-0.177802	0.105173	0.044964	0.038231
LogOfAreas	0.704531	-0.312690	-0.034345	-0.226490	-0.193121
Log_X_Index	0.735860	-0.212375	-0.120561	-0.198690	-0.151720
Log_Y_Index	0.481853	-0.321185	0.062316	-0.221813	-0.161769
Orientation_Index	-0.384696	-0.136713	0.174628	0.013614	0.043389
Luminosity_Index	0.098459	0.154319	0.045295	-0.064744	0.039328
SigmoidOfAreas	0.488878	-0.252488	-0.000462	-0.220091	-0.102046
Pastry	-0.149512	-0.058427	-0.050835	-0.152141	-0.216871
Z_Scratch	-0.165446	-0.064654	-0.056253	-0.168356	-0.239984
K_Scratch	1.000000	-0.098579	-0.085770	-0.256694	-0.365907

```
Stains                -0.098579  1.000000  -0.033518 -0.100313 -0.142991
Dirtiness             -0.085770 -0.033518   1.000000 -0.087278 -0.124411
Bumps                 -0.256694 -0.100313  -0.087278  1.000000 -0.372342
Class                 -0.365907 -0.142991  -0.124411 -0.372342  1.000000

[34 rows x 34 columns]
```

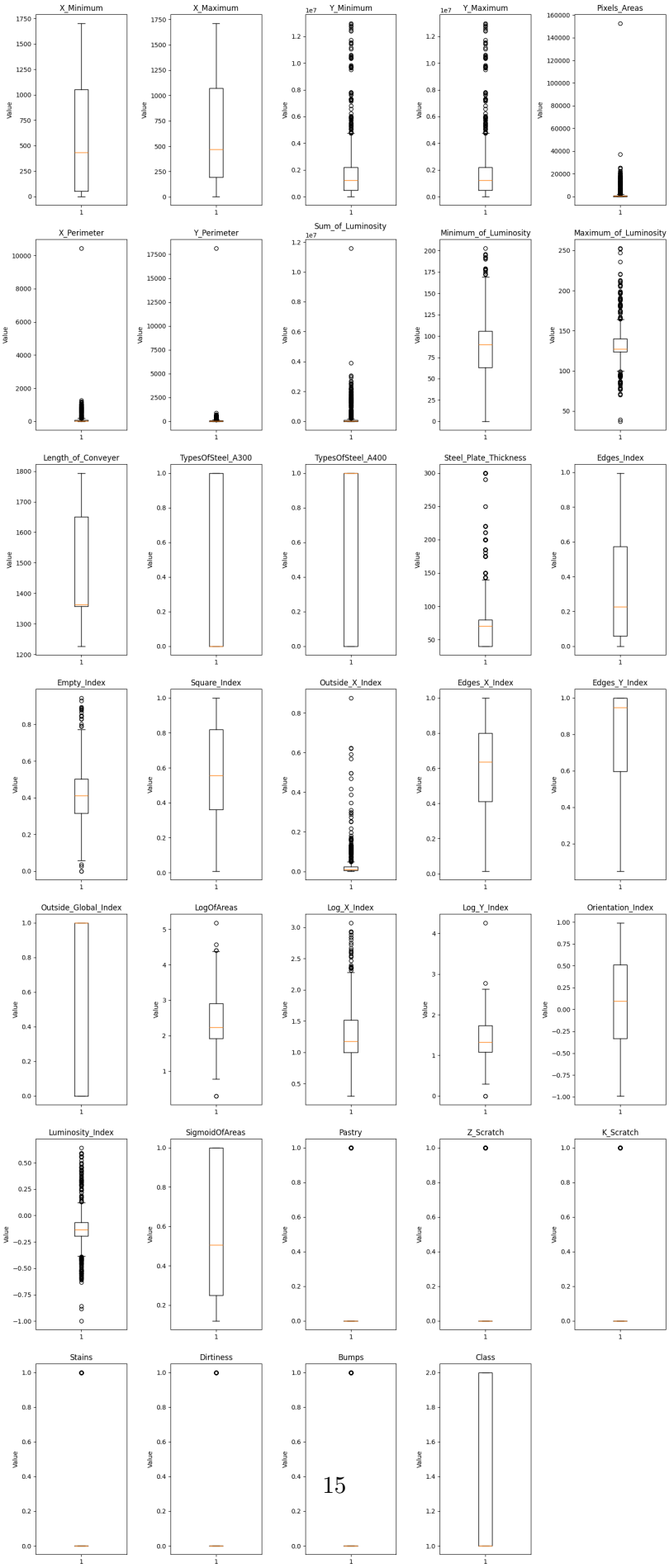
[9]:
```
plt.figure(figsize=(20, 20))
sns.heatmap(corr_matrix, cmap='coolwarm', fmt=".3f", vmin=-1, vmax=1, center=0,␣
 ↪annot=True, square=True)
plt.title("Correlation Heatmap")
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



[10]:
```
plt.figure()
nitems = len(df.columns)
ncols = 5
nrows = (nitems + ncols - 1) // ncols

fig, axes = plt.subplots(nrows, ncols, figsize=(15, 5 * nrows))
axes = axes.flatten()

for i, col in enumerate(df.columns):
    axes[i].boxplot(df[col].dropna())
    axes[i].set_title(col)
```

```
    axes[i].set_ylabel("Value")

for i in range(nitems, len(axes)):
    fig.delaxes(axes[i])

plt.tight_layout()
plt.show()
```

```
<Figure size 640x480 with 0 Axes>
```


X_Minimum
X_Maximum
Y_Minimum
Y_Maximum
Pixels_Areas
X_Perimeter
Y_Perimeter
Sum_of_Luminosity
Minimum_of_Luminosity
Maximum_of_Luminosity
Length_of_Conveyer
TypesOfSteel_A300
TypesOfSteel_A400
Steel_Plate_Thickness
Edges_Index
Empty_Index
Square_Index
Outside_X_Index
Edges_X_Index
Edges_Y_Index
Outside_Global_Index
LogOfAreas
Log_X_Index
Log_Y_Index
Orientation_Index
Luminosity_Index
SigmoidOfAreas
Pastry
Z_Scratch
K_Scratch
Stains
Dirtiness
Bumps
Class
Value
1e7

1 Z-Score outlier detection

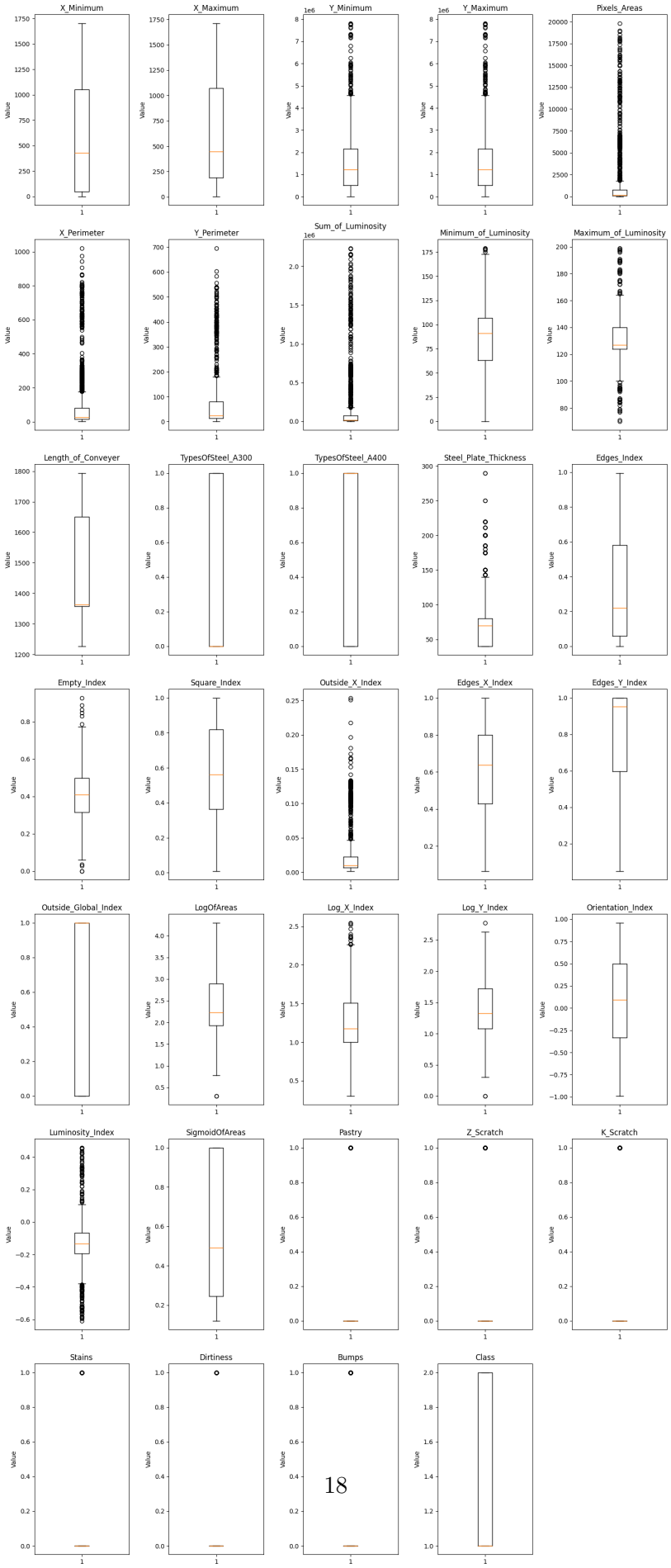
[11]:
```
# All Columns except the ones we're predicting ('Pastry', 'Z_Scratch',␣
 ↪'K_Scratch', 'Stains', 'Dirtiness', 'Bumps', 'Other_Faults_(Class)')
columns_to_check_outliers = [
    'X_Minimum', 'X_Maximum', 'Y_Minimum', 'Y_Maximum', 'Pixels_Areas',␣
 ↪'X_Perimeter',
    'Y_Perimeter', 'Sum_of_Luminosity', 'Minimum_of_Luminosity',␣
 ↪'Maximum_of_Luminosity',
    'Length_of_Conveyer', 'TypesOfSteel_A300', 'TypesOfSteel_A400',␣
 ↪'Steel_Plate_Thickness',
    'Edges_Index', 'Empty_Index', 'Square_Index', 'Outside_X_Index',␣
 ↪'Edges_X_Index',
    'Edges_Y_Index', 'Outside_Global_Index', 'LogOfAreas', 'Log_X_Index',␣
 ↪'Log_Y_Index',
    'Orientation_Index', 'Luminosity_Index', 'SigmoidOfAreas'
]
# Ignoring certain columns without outliers - as seen in the boxplots - to use␣
 ↪a more aggressive outlier detection on the others
columns_to_ignore = [
    'X_Minimum', 'X_Maximum', 'Length_of_Conveyer', 'TypesOfSteel_A300',␣
 ↪'TypesOfSteel_A400',
    'Edges_Index','Square_Index','Edges_X_Index', 'Edges_Y_Index',␣
 ↪'Outside_Global_Index',
    'Orientation_Index', 'SigmoidOfAreas'
]
columns_to_check_outliers = [col for col in columns_to_check_outliers if col␣
 ↪not in columns_to_ignore]
print(columns_to_check_outliers)
z_score = stats.zscore(df[columns_to_check_outliers])
df_clean = df.copy()
df_clean = df_clean[(abs(z_score) < 4).all(axis=1)]
```

```
['Y_Minimum', 'Y_Maximum', 'Pixels_Areas', 'X_Perimeter', 'Y_Perimeter',
'Sum_of_Luminosity', 'Minimum_of_Luminosity', 'Maximum_of_Luminosity',
'Steel_Plate_Thickness', 'Empty_Index', 'Outside_X_Index', 'LogOfAreas',
'Log_X_Index', 'Log_Y_Index', 'Luminosity_Index']
```

[12]:
```
plt.figure()
nitems = len(df_clean.columns)
ncols = 5
nrows = (nitems + ncols - 1) // ncols

fig, axes = plt.subplots(nrows, ncols, figsize=(15, 5 * nrows))
```

```
axes = axes.flatten()

for i, col in enumerate(df_clean.columns):
    axes[i].boxplot(df_clean[col].dropna())
    axes[i].set_title(col)
    axes[i].set_ylabel("Value")

for i in range(nitems, len(axes)):
    fig.delaxes(axes[i])

plt.tight_layout()
plt.show()
```

```
<Figure size 640x480 with 0 Axes>
```


X_Minimum
X_Maximum
Y_Minimum
Y_Maximum
Pixels_Areas
X_Perimeter
Y_Perimeter
Sum_of_Luminosity
Minimum_of_Luminosity
Maximum_of_Luminosity
Length_of_Conveyer
TypesOfSteel_A300
TypesOfSteel_A400
Steel_Plate_Thickness
Edges_Index
Empty_Index
Square_Index
Outside_X_Index
Edges_X_Index
Edges_Y_Index
Outside_Global_Index
LogOfAreas
Log_X_Index
Log_Y_Index
Orientation_Index
Luminosity_Index
SigmoidOfAreas
Pastry
Z_Scratch
K_Scratch
Stains
Dirtiness
Bumps
Class
Value
1

[13]:
```
df_clean.describe()
```

[13]:

	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	Pixels_Areas
count	1822.000000	1822.000000	1.822000e+03	1.822000e+03	1822.000000
mean	568.457190	610.583425	1.545173e+06	1.545216e+06	1659.091109
std	521.583285	499.458726	1.351809e+06	1.351807e+06	3407.213291
min	0.000000	4.000000	6.712000e+03	6.724000e+03	2.000000
25%	50.000000	190.000000	5.144658e+05	5.146172e+05	84.000000
50%	430.500000	446.000000	1.230772e+06	1.230788e+06	170.000000
75%	1051.000000	1071.000000	2.156948e+06	2.156966e+06	780.000000
max	1705.000000	1713.000000	7.818756e+06	7.818807e+06	19818.000000

	X_Perimeter	Y_Perimeter	Sum_of_Luminosity	Minimum_of_Luminosity
count	1822.000000	1822.00000	1.822000e+03	1822.000000
mean	98.555434	68.99067	1.821127e+05	84.665203
std	168.790145	105.22777	3.857515e+05	30.904734
min	2.000000	1.00000	2.500000e+02	0.000000
25%	15.000000	13.00000	9.453500e+03	63.000000
50%	26.000000	24.00000	1.868450e+04	91.000000
75%	80.000000	80.00000	7.780275e+04	107.000000
max	1021.000000	696.00000	2.236201e+06	179.000000

	Maximum_of_Luminosity	…	Orientation_Index	Luminosity_Index
count	1822.000000	…	1822.000000	1822.000000
mean	129.660263	…	0.082325	-0.132847
std	16.070491	…	0.499101	0.133654
min	70.000000	…	-0.991000	-0.609600
25%	124.000000	…	-0.333300	-0.193450
50%	127.000000	…	0.090900	-0.132550
75%	140.000000	…	0.500000	-0.067950
max	199.000000	…	0.960700	0.457300

	SigmoidOfAreas	Pastry	Z_Scratch	K_Scratch	Stains
count	1822.000000	1822.000000	1822.000000	1822.000000	1822.000000
mean	0.579185	0.083425	0.104281	0.197585	0.039517
std	0.338397	0.276599	0.305709	0.398287	0.194875
min	0.119000	0.000000	0.000000	0.000000	0.000000
25%	0.244500	0.000000	0.000000	0.000000	0.000000
50%	0.491300	0.000000	0.000000	0.000000	0.000000
75%	0.999700	0.000000	0.000000	0.000000	0.000000
max	1.000000	1.000000	1.000000	1.000000	1.000000

	Dirtiness	Bumps	Class
count	1822.000000	1822.000000	1822.000000

```
mean       0.030187      0.215697      1.329308
std        0.171147      0.411418      0.470091
min        0.000000      0.000000      1.000000
25%        0.000000      0.000000      1.000000
50%        0.000000      0.000000      1.000000
75%        0.000000      0.000000      2.000000
max        1.000000      1.000000      2.000000

[8 rows x 34 columns]
```

1.0.1 Zhodnotenie Z-Score outlier detection

Napriek tomu, že Z-Score efektívne odstránil väčšinu outlierov, prišli sme o dáta, ktoré nám pomôžu predikovať Pastry, Z Scratch, Stains a Dirtiness a teda Z-Score ne neoptimálny v tomto prípade alebo v aktuálnej konfigurácii.

2 Modifikovaná 5% 95% Metóda

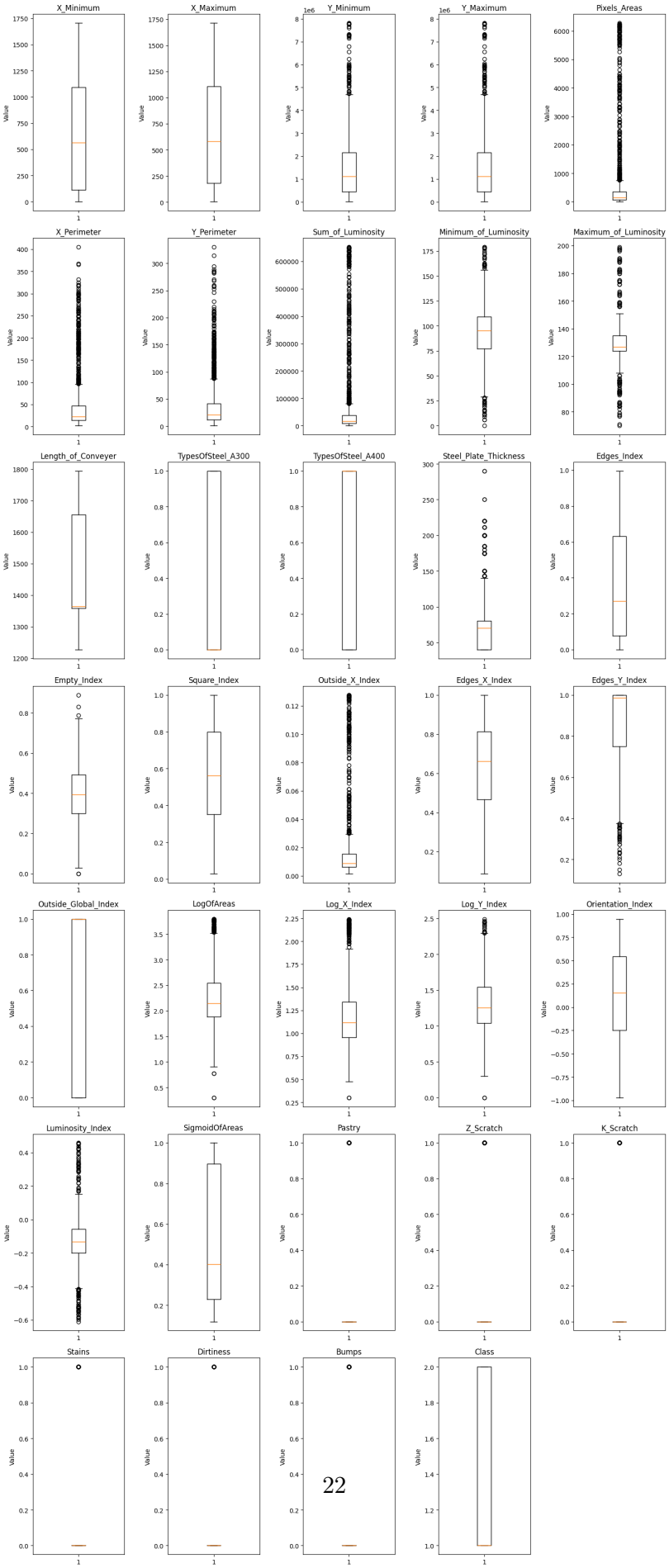
[14]:
```
# All Columns except the ones we're predicting ('Pastry', 'Z_Scratch',␣
 ↪'K_Scratch', 'Stains', 'Dirtiness', 'Bumps', 'Other_Faults_(Class)')
columns_to_check_outliers = [
    'X_Minimum', 'X_Maximum', 'Y_Minimum', 'Y_Maximum', 'Pixels_Areas',␣
 ↪'X_Perimeter',
    'Y_Perimeter', 'Sum_of_Luminosity', 'Minimum_of_Luminosity',␣
 ↪'Maximum_of_Luminosity',
    'TypesOfSteel_A300', 'TypesOfSteel_A400', 'Steel_Plate_Thickness',␣
 ↪'Edges_Index',
    'Empty_Index', 'Square_Index', 'Outside_X_Index', 'Edges_X_Index',␣
 ↪'Edges_Y_Index',
    'Outside_Global_Index', 'LogOfAreas', 'Log_X_Index', 'Log_Y_Index',␣
 ↪'Orientation_Index',
    'Luminosity_Index', 'SigmoidOfAreas'
]
# Ignoring certain columns without outliers - as seen in the boxplots - to use␣
 ↪a more aggressive outlier detection on the others
columns_to_ignore = [
    'X_Minimum', 'X_Maximum', 'Length_of_Conveyer', 'TypesOfSteel_A300',␣
 ↪'TypesOfSteel_A400',
    'Edges_Index','Square_Index','Edges_X_Index', 'Edges_Y_Index',␣
 ↪'Outside_Global_Index',
    'Orientation_Index', 'SigmoidOfAreas',
    # Ignoring columns that were well handled by Z-Score already
    'Y_Minimum', 'Y_Maximum', 'Minimum_of_Luminosity', 'Maximum_of_Luminosity',␣
 ↪'Steel_Plate_Thickness', 'Empty_Index',
    'Log_X_Index', 'Log_Y_Index', 'Luminosity_Index'
]
```

```
columns_to_check_outliers = [col for col in columns_to_check_outliers if col␣
 ↪not in columns_to_ignore]
print(columns_to_check_outliers)

shaving_ranges = [
    (0.0, 0.98), (0.0, 0.98), (0.0, 0.98), (0.0, 0.98), (0.0, 0.98), (0.0, 0.98)
]

for idx, col in enumerate(columns_to_check_outliers):
    lower = 0
    higher = 1
    df_CO_lower = df_clean[col].quantile(shaving_ranges[idx][lower])
    df_CO_upper = df_clean[col].quantile(shaving_ranges[idx][higher])

    df_clean[col] = df[col].where(
        (df_clean[col] >= df_CO_lower) & (df_clean[col] <= df_CO_upper)
    )
    df_clean.dropna(inplace = True)
```

```
['Pixels_Areas', 'X_Perimeter', 'Y_Perimeter', 'Sum_of_Luminosity',
'Outside_X_Index', 'LogOfAreas']
```

[15]:
```
plt.figure()
nitems = len(df_clean.columns)
ncols = 5
nrows = (nitems + ncols - 1) // ncols

fig, axes = plt.subplots(nrows, ncols, figsize=(15, 5 * nrows))
axes = axes.flatten()

for i, col in enumerate(df_clean.columns):
    axes[i].boxplot(df_clean[col].dropna())
    axes[i].set_title(col)
    axes[i].set_ylabel("Value")

for i in range(nitems, len(axes)):
    fig.delaxes(axes[i])

plt.tight_layout()
plt.show()
```

```
<Figure size 640x480 with 0 Axes>
```


X_Minimum
X_Maximum
Y_Minimum
Y_Maximum
Pixels_Areas
X_Perimeter
Y_Perimeter
Sum_of_Luminosity
Minimum_of_Luminosity
Maximum_of_Luminosity
Length_of_Conveyer
TypesOfSteel_A300
TypesOfSteel_A400
Steel_Plate_Thickness
Edges_Index
Empty_Index
Square_Index
Outside_X_Index
Edges_X_Index
Edges_Y_Index
Outside_Global_Index
LogOfAreas
Log_X_Index
Log_Y_Index
Orientation_Index
Luminosity_Index
SigmoidOfAreas
Pastry
Z_Scratch
K_Scratch
Stains
Dirtiness
Bumps
Class
Value
1

[16]:
```
df_clean.describe()
```

[16]:

	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	Pixels_Areas
count	1613.000000	1613.000000	1.613000e+03	1.613000e+03	1613.000000
mean	629.401116	655.522009	1.513393e+06	1.513424e+06	632.513329
std	517.427471	507.119546	1.403003e+06	1.403001e+06	1334.099392
min	0.000000	4.000000	6.712000e+03	6.724000e+03	2.000000
25%	114.000000	181.000000	4.479430e+05	4.479920e+05	77.000000
50%	563.000000	583.000000	1.116878e+06	1.116892e+06	141.000000
75%	1090.000000	1106.000000	2.150529e+06	2.150756e+06	349.000000
max	1705.000000	1713.000000	7.818756e+06	7.818807e+06	6277.000000

	X_Perimeter	Y_Perimeter	Sum_of_Luminosity	Minimum_of_Luminosity
count	1613.000000	1613.000000	1613.000000	1613.000000
mean	48.324241	39.787353	66874.983881	90.650961
std	64.058738	47.378852	139509.821414	27.155015
min	2.000000	1.000000	250.000000	0.000000
25%	14.000000	12.000000	8602.000000	77.000000
50%	22.000000	21.000000	16182.000000	95.000000
75%	47.000000	42.000000	37460.000000	109.000000
max	405.000000	330.000000	652005.000000	179.000000

	Maximum_of_Luminosity	…	Orientation_Index	Luminosity_Index
count	1613.000000	…	1613.000000	1613.000000
mean	129.055797	…	0.121622	-0.131680
std	16.596791	…	0.495092	0.140006
min	70.000000	…	-0.970600	-0.609600
25%	124.000000	…	-0.250000	-0.199500
50%	127.000000	…	0.153900	-0.132600
75%	135.000000	…	0.545400	-0.057500
max	199.000000	…	0.946700	0.457300

	SigmoidOfAreas	Pastry	Z_Scratch	K_Scratch	Stains
count	1613.000000	1613.000000	1613.000000	1613.000000	1613.000000
mean	0.524665	0.091754	0.115313	0.106634	0.044637
std	0.321606	0.288769	0.319498	0.308743	0.206570
min	0.119000	0.000000	0.000000	0.000000	0.000000
25%	0.230000	0.000000	0.000000	0.000000	0.000000
50%	0.402500	0.000000	0.000000	0.000000	0.000000
75%	0.897100	0.000000	0.000000	0.000000	0.000000
max	1.000000	1.000000	1.000000	1.000000	1.000000

	Dirtiness	Bumps	Class
count	1613.000000	1613.000000	1613.000000

```
mean      0.034098     0.243025     1.364538
std       0.181537     0.429043     0.481450
min       0.000000     0.000000     1.000000
25%       0.000000     0.000000     1.000000
50%       0.000000     0.000000     1.000000
75%       0.000000     0.000000     2.000000
max       1.000000     1.000000     2.000000

[8 rows x 34 columns]
```

[17]:
```
df_clean.head()
```

[17]:

	X_Minimum	X_Maximum	Y_Minimum	Y_Maximum	Pixels_Areas	X_Perimeter
0	42	50	270900	270944	267.0	17.0
1	645	651	2538079	2538108	108.0	10.0
2	829	835	1553913	1553931	71.0	8.0
3	853	860	369370	369415	176.0	13.0
4	1289	1306	498078	498335	2409.0	60.0

	Y_Perimeter	Sum_of_Luminosity	Minimum_of_Luminosity
0	44.0	24220.0	76
1	30.0	11397.0	84
2	19.0	7972.0	99
3	45.0	18996.0	99
4	260.0	246930.0	37

	Maximum_of_Luminosity	…	Orientation_Index	Luminosity_Index
0	108	…	0.8182	-0.2913
1	123	…	0.7931	-0.1756
2	125	…	0.6667	-0.1228
3	126	…	0.8444	-0.1568
4	126	…	0.9338	-0.1992

	SigmoidOfAreas	Pastry	Z_Scratch	K_Scratch	Stains	Dirtiness	Bumps
0	0.5822	1	0	0	0	0	0
1	0.2984	1	0	0	0	0	0
2	0.2150	1	0	0	0	0	0
3	0.5212	1	0	0	0	0	0
4	1.0000	1	0	0	0	0	0

	Class
0	1
1	1
2	1
3	1
4	1

```
[5 rows x 34 columns]
```

[ ]: