Pixel Data: Project Two

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Acknowledgements

One of the resources of note for this project include the Elements of Statistical Learning book. It is my intention to acknowledge the sources of information used for the work herein. This book was an instrumental asset in the data mining elements of the project with its wealth of well-documented knowledge on the applications of statistical learning techniques. I have also learnt a lot about R programming from various open source platforms on conducting data analysis using R. Additionally, I also wish to take time and appreciate the various data analysis-rich open source platforms that have helped me gain more skills in using R.

List of Notations

List of Keywords

Configurations

Below is the working directory that was created for the project. If this script is run from another computer, this will have to ne changed accordingly. We also load the dataset that we are going to use for the project.

```r
#clearing the work space

rm(list = ls()
)



#checking the current working directory

getwd()
```

```
## [1] "C:/Users/Tshepo Ralehoko/Downloads/Data Science/Data Science - R/Projects/Pixel Project 2"
```

```r
#setting my own working directory

setwd(file.path("C:", "Users", "Tshepo Ralehoko", "Downloads", "Data Science", "Data Science - R", "Project
)



#loading the dataset into R

pixel = read.csv(file.path("C:", "Users", "Tshepo Ralehoko", "Downloads", "Data Science", "MSc Data Scienc
)
```

Introduction

Data Description and Data Summary

```r
#printing a few of the last records of our dataset

tail(x = pixel, n = 5)
```

```
##      Digit Pixel_1 Pixel_2 Pixel_3 Pixel_4 Pixel_5 Pixel_6 Pixel_7 Pixel_8
## 2496     6       0       0       0       0       0       0       0       0
## 2497     2       0       0       0       0       0       0       0       0
## 2498     4       0       0       0       0       0       0       0       0
## 2499     4       0       0       0       0       0       0       0       0
## 2500     4       0       0       0       0       0       0       0       0

##      Pixel_9 Pixel_10 Pixel_11 Pixel_12 Pixel_13 Pixel_14 Pixel_15
## 2496       0        0        0        0        0        0        0
## 2497       0        0        0        0        0        0        0
## 2498       0        0        0        0        0        0        0
## 2499       0        0        0        0        0        0        0
## 2500       0        0        0        0        0        0        0

##      Pixel_16 Pixel_17 Pixel_18 Pixel_19 Pixel_20 Pixel_21 Pixel_22
## 2496        0        0        0        0        0        0        0
## 2497        0        0        0        0        0        0        0
## 2498        0        0        0        0        0        0        0
## 2499        0        0        0        0        0        0        0
## 2500        0        0        0        0        0        0        0

##      Pixel_23 Pixel_24 Pixel_25 Pixel_26 Pixel_27 Pixel_28 Pixel_29
## 2496        0        0        0        0        0        0        0
## 2497        0        0        0        0        0        0        0
## 2498        0        0        0        0        0        0        0
## 2499        0        0        0        0        0        0        0
## 2500        0        0        0        0        0        0        0

##      Pixel_30 Pixel_31 Pixel_32 Pixel_33 Pixel_34 Pixel_35 Pixel_36
## 2496        0        0        0        0        0        0        0
```

```
## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_37 Pixel_38 Pixel_39 Pixel_40 Pixel_41 Pixel_42 Pixel_43

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_44 Pixel_45 Pixel_46 Pixel_47 Pixel_48 Pixel_49 Pixel_50

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_51 Pixel_52 Pixel_53 Pixel_54 Pixel_55 Pixel_56 Pixel_57

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_58 Pixel_59 Pixel_60 Pixel_61 Pixel_62 Pixel_63 Pixel_64

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0
```

```
## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##        Pixel_65 Pixel_66 Pixel_67 Pixel_68 Pixel_69 Pixel_70 Pixel_71

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##        Pixel_72 Pixel_73 Pixel_74 Pixel_75 Pixel_76 Pixel_77 Pixel_78

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##        Pixel_79 Pixel_80 Pixel_81 Pixel_82 Pixel_83 Pixel_84 Pixel_85

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##        Pixel_86 Pixel_87 Pixel_88 Pixel_89 Pixel_90 Pixel_91 Pixel_92

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0
```

```
##      Pixel_93 Pixel_94 Pixel_95 Pixel_96 Pixel_97 Pixel_98 Pixel_99
## 2496        0        0        0        0        0        0        0
## 2497        0        0        0        0        0        0        0
## 2498        0        0        0        0        0        0        0
## 2499        0        0        0        0        0        0        0
## 2500        0        0        0        0        0        0        0
##      Pixel_100 Pixel_101 Pixel_102 Pixel_103 Pixel_104 Pixel_105 Pixel_106
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_107 Pixel_108 Pixel_109 Pixel_110 Pixel_111 Pixel_112 Pixel_113
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_114 Pixel_115 Pixel_116 Pixel_117 Pixel_118 Pixel_119 Pixel_120
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_121 Pixel_122 Pixel_123 Pixel_124 Pixel_125 Pixel_126 Pixel_127
## 2496         0         0         0         0         0         0         0
```

```
## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0           0           0           0

##        Pixel_128 Pixel_129 Pixel_130 Pixel_131 Pixel_132 Pixel_133 Pixel_134

## 2496           0           0           0           0           0           0           0

## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0           0           0           0

##        Pixel_135 Pixel_136 Pixel_137 Pixel_138 Pixel_139 Pixel_140 Pixel_141

## 2496           0           0           0           0           0           0           0

## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0           0           0           0

##        Pixel_142 Pixel_143 Pixel_144 Pixel_145 Pixel_146 Pixel_147 Pixel_148

## 2496           0           0           0           0           0           0           0

## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0           0           0           0

##        Pixel_149 Pixel_150 Pixel_151 Pixel_152 Pixel_153 Pixel_154 Pixel_155

## 2496           0           0           0           0           0           0           0

## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0
```

```
## 2499            0            0            0            0            0            0            0

## 2500            0            0            0            0            0            0            0

##       Pixel_156 Pixel_157 Pixel_158 Pixel_159 Pixel_160 Pixel_161 Pixel_162

## 2496            0            0            0            0            0            0            0

## 2497            0            0            0            0            0            0            0

## 2498            0            0            0            0            0            0            0

## 2499            0            0            0            0            0            0            0

## 2500            0            0            0            0            0            0            0

##       Pixel_163 Pixel_164 Pixel_165 Pixel_166 Pixel_167 Pixel_168 Pixel_169

## 2496            0            0            0            0            0            0            0

## 2497            0            0            0            0            0            0            0

## 2498            0            0            0            0            0            0            0

## 2499            0            0            0            0            0            0            0

## 2500            0            0            0            0            0            0            0

##       Pixel_170 Pixel_171 Pixel_172 Pixel_173 Pixel_174 Pixel_175 Pixel_176

## 2496            0            0            0            0            0            0            0

## 2497            0            0            0            0            0           55          192

## 2498            0            0            0            0            0            0            0

## 2499            0            0            0            0            0            0            0

## 2500            0            0            0            0            0            0            0

##       Pixel_177 Pixel_178 Pixel_179 Pixel_180 Pixel_181 Pixel_182 Pixel_183

## 2496            0            0            0            0            0            0            0

## 2497           80            0            0            0            0            0            0

## 2498            0            0            0            0            0            0            0

## 2499            0            0            0            0            0            0            0

## 2500            0            0            0            0            0            0            0
```

```
##      Pixel_184 Pixel_185 Pixel_186 Pixel_187 Pixel_188 Pixel_189 Pixel_190
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_191 Pixel_192 Pixel_193 Pixel_194 Pixel_195 Pixel_196 Pixel_197
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_198 Pixel_199 Pixel_200 Pixel_201 Pixel_202 Pixel_203 Pixel_204
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         8       197       252
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_205 Pixel_206 Pixel_207 Pixel_208 Pixel_209 Pixel_210 Pixel_211
## 2496         0         0         0         0        70       158       245
## 2497       211         0         0         0         0         0         0
## 2498         0         7        66       157       157       111        21
## 2499         0         0         0         0       119       184       184
## 2500         0         0         0         0         0         0         0
##      Pixel_212 Pixel_213 Pixel_214 Pixel_215 Pixel_216 Pixel_217 Pixel_218
## 2496       245       245       245       147         6         0         0
```

```
## 2497          0          0          0          0          0          0          0
## 2498          0          0          0          0          0          0          0
## 2499        184        123         25          0          0          0          0
## 2500          0          0          0          0          0          0          0
##      Pixel_219 Pixel_220 Pixel_221 Pixel_222 Pixel_223 Pixel_224 Pixel_225
## 2496          0          0          0          0          0          0          0
## 2497          0          0          0          0          0          0          0
## 2498          0          0          0          0          0          0          0
## 2499          0          0          0          0          0          0          0
## 2500          0          0          0          0          0          0          0
##      Pixel_226 Pixel_227 Pixel_228 Pixel_229 Pixel_230 Pixel_231 Pixel_232
## 2496          0          0          0          0          0          0          0
## 2497          0          0          0          0         22        252        252
## 2498          0          0          0          0          0          0          5
## 2499          0          0          0          0          0          0          0
## 2500          0          0          0          0          0          0         25
##      Pixel_233 Pixel_234 Pixel_235 Pixel_236 Pixel_237 Pixel_238 Pixel_239
## 2496          0          0         39        188        241        254        254
## 2497        211          0          0          0          0          0          0
## 2498         49        145        252        252        252        252        216
## 2499          0          0         85        155        236        252        252
## 2500         48         48         48         55        141        197        155
##      Pixel_240 Pixel_241 Pixel_242 Pixel_243 Pixel_244 Pixel_245 Pixel_246
## 2496        254        254        254        254        150         31          0
## 2497          0         85         83        128         32          0          0
## 2498          8          0          0          0          0          0          0
```

```
## 2499           252         253         202          68           0           0           0

## 2500           107           0           0           0           0           0           0

##        Pixel_247 Pixel_248 Pixel_249 Pixel_250 Pixel_251 Pixel_252 Pixel_253

## 2496             0           0           0           0           0           0           0

## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##        Pixel_254 Pixel_255 Pixel_256 Pixel_257 Pixel_258 Pixel_259 Pixel_260

## 2496             0           0           0           0           0           0           8

## 2497             0           0           0           0          22         252         252

## 2498             0           0           0           0           0           3         136

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0          37         186

##        Pixel_261 Pixel_262 Pixel_263 Pixel_264 Pixel_265 Pixel_266 Pixel_267

## 2496           119         156         243         254         254         254         254

## 2497           211           0           0           0           0           0          22

## 2498           252         252         252         252         252         252         252

## 2499             0         136         250         253         252         252         157

## 2500           254         254         250         235         235         235         251

##        Pixel_268 Pixel_269 Pixel_270 Pixel_271 Pixel_272 Pixel_273 Pixel_274

## 2496           254         254         254         254         254         146           0

## 2497           160         225         252         253          63           0           0

## 2498            40           0           0           0           0           0           0

## 2499           242         253         252         183           0           0           0

## 2500           254           0           0           0           0           0           0
```

##	Pixel_275	Pixel_276	Pixel_277	Pixel_278	Pixel_279	Pixel_280	Pixel_281
## 2496	0	0	0	0	0	0	0
## 2497	0	0	0	0	0	0	0
## 2498	0	0	0	0	0	0	0
## 2499	0	0	0	0	0	0	0
## 2500	0	0	0	0	0	0	0

##	Pixel_282	Pixel_283	Pixel_284	Pixel_285	Pixel_286	Pixel_287	Pixel_288
## 2496	0	0	0	0	0	8	168
## 2497	0	0	0	0	22	252	252
## 2498	0	0	0	0	0	197	252
## 2499	0	0	0	0	0	13	118
## 2500	0	0	0	0	0	227	241

##	Pixel_289	Pixel_290	Pixel_291	Pixel_292	Pixel_293	Pixel_294	Pixel_295
## 2496	255	254	255	254	226	181	145
## 2497	211	0	0	0	0	0	85
## 2498	242	100	60	60	60	225	252
## 2499	253	253	253	255	218	32	0
## 2500	169	106	61	0	0	0	217

##	Pixel_296	Pixel_297	Pixel_298	Pixel_299	Pixel_300	Pixel_301	Pixel_302
## 2496	91	181	247	254	254	237	33
## 2497	252	252	252	253	186	9	0
## 2498	131	0	0	0	0	0	0
## 2499	116	255	253	184	0	0	0
## 2500	254	0	0	0	0	0	0

##	Pixel_303	Pixel_304	Pixel_305	Pixel_306	Pixel_307	Pixel_308	Pixel_309
## 2496	0	0	0	0	0	0	0

```
## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##      Pixel_310 Pixel_311 Pixel_312 Pixel_313 Pixel_314 Pixel_315 Pixel_316

## 2496             0           0           0           0           6         168         255

## 2497             0           0           0           0           9         204         253

## 2498             0           0           0           0           0         168         156

## 2499             0           0           0           0           0         212         252

## 2500             0           0           0           0           0           9           8

##      Pixel_317 Pixel_318 Pixel_319 Pixel_320 Pixel_321 Pixel_322 Pixel_323

## 2496           254         254         248         175          40           0           0

## 2497           254          63           0           0           0           0         129

## 2498            41           0           0           0          29         229         252

## 2499           252         252         252         144          33           0           0

## 2500             0           0           0           0           0          13         225

##      Pixel_324 Pixel_325 Pixel_326 Pixel_327 Pixel_328 Pixel_329 Pixel_330

## 2496             2          48         241         254         254         254          53

## 2497           253         253         253         255         253          21           0

## 2498           131           0           0           0           0           0           0

## 2499           116         253         252         183           0           0           0

## 2500           162           0           0           0           0           0           0

##      Pixel_331 Pixel_332 Pixel_333 Pixel_334 Pixel_335 Pixel_336 Pixel_337

## 2496             0           0           0           0           0           0           0

## 2497             0           0           0           0           0           0           0

## 2498             0          33          85          45           0           0           0
```

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```
## 2499              0           0           0           0           0           0           0

## 2500              0           0           0           0           0           0           0

##       Pixel_338 Pixel_339 Pixel_340 Pixel_341 Pixel_342 Pixel_343 Pixel_344

## 2496              0           0           0          24         195         254         254

## 2497              0           0           0           0           0         133         252

## 2498              0           0           0           0           0           0           0

## 2499              0           0           0           0           0         190         252

## 2500              0           0           0           0           0           0           0

##       Pixel_345 Pixel_346 Pixel_347 Pixel_348 Pixel_349 Pixel_350 Pixel_351

## 2496            254         213          67           0           0           0           0

## 2497            253         205         130          36           0           0         121

## 2498              0           0           0           0         130         252         252

## 2499            252         195         130           0           0           0           0

## 2500              0           0           0           0           0         103         254

##       Pixel_352 Pixel_353 Pixel_354 Pixel_355 Pixel_356 Pixel_357 Pixel_358

## 2496            126         254         254         254         254         254         150

## 2497            252         252         252         253         189           5           0

## 2498            131           0           0           0           0           0          28

## 2499            116         253         252         183           0           0          70

## 2500            114           0           0           0           0           0           0

##       Pixel_359 Pixel_360 Pixel_361 Pixel_362 Pixel_363 Pixel_364 Pixel_365

## 2496              0           0           0           0           0           0           0

## 2497              0           0           0           0           0           0           0

## 2498             97         214         252         177           0           0           0

## 2499            142         184          90          70           0           0           0

## 2500              0           0           0           0           0           0           0
```

```
##       Pixel_366 Pixel_367 Pixel_368 Pixel_369 Pixel_370 Pixel_371 Pixel_372
## 2496         0         0         5       212       254       254       253
## 2497         0         0         0         0         0        32       179
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         5        45
## 2500         0         0         0         0         0         0         0
##       Pixel_373 Pixel_374 Pixel_375 Pixel_376 Pixel_377 Pixel_378 Pixel_379
## 2496       109        15         0         0         0         0        77
## 2497       253       252       251       241       188       171       221
## 2498         0         0         0         0        96       252       252
## 2499        45         9         0         0         0         0         0
## 2500         0         0         0         0         0       221       232
##       Pixel_380 Pixel_381 Pixel_382 Pixel_383 Pixel_384 Pixel_385 Pixel_386
## 2496       252       254       192       185       254       254       195
## 2497       252       252       252       232        84         0         0
## 2498        22         0         0         0        96       229       236
## 2499       116       253       252       183        34       197       253
## 2500        17         0         0         0         0         0         0
##       Pixel_387 Pixel_388 Pixel_389 Pixel_390 Pixel_391 Pixel_392 Pixel_393
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498       252       252       252        33         0         0         0
## 2499       252       252       252       252         0         0         0
## 2500         0         0         0         0         0         0         0
##       Pixel_394 Pixel_395 Pixel_396 Pixel_397 Pixel_398 Pixel_399 Pixel_400
## 2496         0        29       233       254       254       238        71
```

```
## 2497           0           0           0           0           0           0          80

## 2498           0           0           0           0           0           0           0

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0           0           0           0

##      Pixel_401 Pixel_402 Pixel_403 Pixel_404 Pixel_405 Pixel_406 Pixel_407

## 2496           0           0           0           0           0          90         231

## 2497         200         252         252         252         252         253         252

## 2498           0           0           0           0          85         252         252

## 2499           0           0           0           0           0           0           0

## 2500           0           0           0           0         110         255          73

##      Pixel_408 Pixel_409 Pixel_410 Pixel_411 Pixel_412 Pixel_413 Pixel_414

## 2496         254         238          61         172         254         254         254

## 2497         252         252         252         115           0           0           0

## 2498          69          64         121         138         248         252         252

## 2499         168         253         252         246         238         252         253

## 2500           0           0           0           3          67           5           0

##      Pixel_415 Pixel_416 Pixel_417 Pixel_418 Pixel_419 Pixel_420 Pixel_421

## 2496           0           0           0           0           0           0           0

## 2497           0           0           0           0           0           0           0

## 2498         154         131          22           1           0           0           0

## 2499         252         252         210          85           0           0           0

## 2500           0           0           0           0           0           0           0

##      Pixel_422 Pixel_423 Pixel_424 Pixel_425 Pixel_426 Pixel_427 Pixel_428

## 2496           0         171         254         254         181          55           0

## 2497           0           0           0           0           0           0           0

## 2498           0           0           0           0           0           0           0
```

```
## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_429 Pixel_430 Pixel_431 Pixel_432 Pixel_433 Pixel_434 Pixel_435

## 2496          0          0          0          0         39        231        254

## 2497          7        165        200        252        252        253        252

## 2498          0          3         13         13        208        253        253

## 2499          0          0          0          0          0          0         51

## 2500          0         26         38         80        218        254        149

##      Pixel_436 Pixel_437 Pixel_438 Pixel_439 Pixel_440 Pixel_441 Pixel_442

## 2496        254        135          0         89        254        254        254

## 2497        252        252        252          0          0          0          0

## 2498        253        255        253        253        245        212         87

## 2499        243        255        253        253        253        253        231

## 2500        202        227        226        227        254        228        149

##      Pixel_443 Pixel_444 Pixel_445 Pixel_446 Pixel_447 Pixel_448 Pixel_449

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499        116        116         21          0          0          0          0

## 2500        132        132         87         38          0          0          0

##      Pixel_450 Pixel_451 Pixel_452 Pixel_453 Pixel_454 Pixel_455 Pixel_456

## 2496          0        171        213        140          2          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          3

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0         16
```

```
##      Pixel_457 Pixel_458 Pixel_459 Pixel_460 Pixel_461 Pixel_462 Pixel_463

## 2496         0         0         0         0       159       254       254

## 2497         0         0         9        35        45        62       217

## 2498       100       165       252       252       252       252       252

## 2499         0         0         0         0        30        47       174

## 2500       142       235       254       254       254       254       253

##      Pixel_464 Pixel_465 Pixel_466 Pixel_467 Pixel_468 Pixel_469 Pixel_470

## 2496       249        61         0       170       254       254       237

## 2497       253       253       253         0         0         0         0

## 2498       252       253       238       153        36         0         0

## 2499       252       253       252       252       214       153        42

## 2500       244       185       150       150       150       237       244

##      Pixel_471 Pixel_472 Pixel_473 Pixel_474 Pixel_475 Pixel_476 Pixel_477

## 2496         0         0         0         0         0         0         0

## 2497         0         0         0         0         0         0         0

## 2498         0         0         0         0         0         0         0

## 2499         0         0         0         0         0         0         0

## 2500       244       244       244       139         0         0         0

##      Pixel_478 Pixel_479 Pixel_480 Pixel_481 Pixel_482 Pixel_483 Pixel_484

## 2496         0         0         0         0         0         0         0

## 2497         0         0         0         0         0         0         0

## 2498         0         0         0         0         0         0        79

## 2499         0         0         0         0         0         0         0

## 2500         0         0         0         0         0        20       137

##      Pixel_485 Pixel_486 Pixel_487 Pixel_488 Pixel_489 Pixel_490 Pixel_491

## 2496         0         0         0        40       242       254       254
```

```
## 2497          0          0          0          0          0          0        155

## 2498        238        252        252        252        252        252        252

## 2499          0          0          0        132        228        252        252

## 2500        254        203        192        254        228         88         75

##      Pixel_492 Pixel_493 Pixel_494 Pixel_495 Pixel_496 Pixel_497 Pixel_498

## 2496        187          0         16        235        254        254        115

## 2497        252        252        252          0          0          0          0

## 2498        160         96         41          0          0          0          0

## 2499        252        253        240        100         13          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_499 Pixel_500 Pixel_501 Pixel_502 Pixel_503 Pixel_504 Pixel_505

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_506 Pixel_507 Pixel_508 Pixel_509 Pixel_510 Pixel_511 Pixel_512

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          5        151

##      Pixel_513 Pixel_514 Pixel_515 Pixel_516 Pixel_517 Pixel_518 Pixel_519

## 2496          0          0          0        108        254        254        254

## 2497          0          0          0          0          0          0         43

## 2498         52         84         84        131        252        252        156
```

```
## 2499          26       134       207       253       252       252       252

## 2500         129         6        48       250        68         0         0

##       Pixel_520 Pixel_521 Pixel_522 Pixel_523 Pixel_524 Pixel_525 Pixel_526

## 2496         120         0        77       254       254       247        41

## 2497         242       252       252         0         0         0         0

## 2498           4         0         0         0         0         0         0

## 2499         252       245        79         0         0         0         0

## 2500           0         0         0         0         0         0         0

##       Pixel_527 Pixel_528 Pixel_529 Pixel_530 Pixel_531 Pixel_532 Pixel_533

## 2496           0         0         0         0         0         0         0

## 2497           0         0         0         0         0         0         0

## 2498           0         0         0         0         0         0         0

## 2499           0         0         0         0         0         0         0

## 2500           0         0         0         0         0         0         0

##       Pixel_534 Pixel_535 Pixel_536 Pixel_537 Pixel_538 Pixel_539 Pixel_540

## 2496           0         0         0         0         0         0         0

## 2497           0         0         0         0         0         0         0

## 2498           0         0         0         0         0         0         0

## 2499           0         0         0         0         0         0        74

## 2500           0         0         0         0         0         0         0

##       Pixel_541 Pixel_542 Pixel_543 Pixel_544 Pixel_545 Pixel_546 Pixel_547

## 2496           0         0         0       156       254       254       254

## 2497           0         0         0         0         0         0         0

## 2498           0         0         0       102       252       252        23

## 2499         205       252       252       253       252       252       252

## 2500           0         0        44       182         0         0         0
```

```
##      Pixel_548 Pixel_549 Pixel_550 Pixel_551 Pixel_552 Pixel_553 Pixel_554
## 2496       216       182       218       254       254       123         0
## 2497       232       252       252         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499       252       126         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_555 Pixel_556 Pixel_557 Pixel_558 Pixel_559 Pixel_560 Pixel_561
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_562 Pixel_563 Pixel_564 Pixel_565 Pixel_566 Pixel_567 Pixel_568
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0        76       212
## 2500         0         0         0         0         0         0         0
##      Pixel_569 Pixel_570 Pixel_571 Pixel_572 Pixel_573 Pixel_574 Pixel_575
## 2496         0         0         0       114       254       254       254
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0       193       252       252        23
## 2499       253       253       253       242       157        63       210
## 2500         0         0         0         0         0         0         0
##      Pixel_576 Pixel_577 Pixel_578 Pixel_579 Pixel_580 Pixel_581 Pixel_582
## 2496       254       254       254       249       182        10         0
```

```
## 2497         232      252      252        0        0        0        0

## 2498           0        0        0        0        0        0        0

## 2499         178        0        0        0        0        0        0

## 2500           0        0        0        0        0        0        0

##      Pixel_583 Pixel_584 Pixel_585 Pixel_586 Pixel_587 Pixel_588 Pixel_589

## 2496           0        0        0        0        0        0        0

## 2497           0        0        0        0        0        0        0

## 2498           0        0        0        0        0        0        0

## 2499           0        0        0        0        0        0        0

## 2500           0        0        0        0        0        0        0

##      Pixel_590 Pixel_591 Pixel_592 Pixel_593 Pixel_594 Pixel_595 Pixel_596

## 2496           0        0        0        0        0        0        0

## 2497           0        0        0        0        0        0        0

## 2498           0        0        0        0        0        0        0

## 2499           0        0        0        0        0      118      252

## 2500           0        0        0        0        0        0        0

##      Pixel_597 Pixel_598 Pixel_599 Pixel_600 Pixel_601 Pixel_602 Pixel_603

## 2496           0        0        0       73      241      254      254

## 2497           0        0        0        0        0        0        0

## 2498           0        0        0      152      252      220       16

## 2499         252      252      210       42        0        0        0

## 2500           0        0        0        0        0        0        0

##      Pixel_604 Pixel_605 Pixel_606 Pixel_607 Pixel_608 Pixel_609 Pixel_610

## 2496         254      254      221       95        0        0        0

## 2497         216      253      253       62        0        0        0

## 2498           0        0        0        0        0        0        0
```

```
## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_611 Pixel_612 Pixel_613 Pixel_614 Pixel_615 Pixel_616 Pixel_617

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_618 Pixel_619 Pixel_620 Pixel_621 Pixel_622 Pixel_623 Pixel_624

## 2496          0          0          0          0          0          0          0

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          7         90

## 2500          0          0          0          0          0          0          0

##      Pixel_625 Pixel_626 Pixel_627 Pixel_628 Pixel_629 Pixel_630 Pixel_631

## 2496          0          0          0          0         29        198        244

## 2497          0          0          0          0          0          0          0

## 2498          0          0          0         11         36         22          0

## 2499        183        141          6          0          0          0          0

## 2500          0          0          0          0          0          0          0

##      Pixel_632 Pixel_633 Pixel_634 Pixel_635 Pixel_636 Pixel_637 Pixel_638

## 2496        231        140         29          0          0          0          0

## 2497        206        252        252        106          0          0          0

## 2498          0          0          0          0          0          0          0

## 2499          0          0          0          0          0          0          0

## 2500          0          0          0          0          0          0          0
```

```
##      Pixel_639 Pixel_640 Pixel_641 Pixel_642 Pixel_643 Pixel_644 Pixel_645
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_646 Pixel_647 Pixel_648 Pixel_649 Pixel_650 Pixel_651 Pixel_652
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_653 Pixel_654 Pixel_655 Pixel_656 Pixel_657 Pixel_658 Pixel_659
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_660 Pixel_661 Pixel_662 Pixel_663 Pixel_664 Pixel_665 Pixel_666
## 2496         0         0         0         0         0         0         0
## 2497       127       252       252       106         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_667 Pixel_668 Pixel_669 Pixel_670 Pixel_671 Pixel_672 Pixel_673
## 2496         0         0         0         0         0         0         0
```

```
## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##       Pixel_674 Pixel_675 Pixel_676 Pixel_677 Pixel_678 Pixel_679 Pixel_680

## 2496             0           0           0           0           0           0           0

## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##       Pixel_681 Pixel_682 Pixel_683 Pixel_684 Pixel_685 Pixel_686 Pixel_687

## 2496             0           0           0           0           0           0           0

## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##       Pixel_688 Pixel_689 Pixel_690 Pixel_691 Pixel_692 Pixel_693 Pixel_694

## 2496             0           0           0           0           0           0           0

## 2497            22         252         252          80           0           0           0

## 2498             0           0           0           0           0           0           0

## 2499             0           0           0           0           0           0           0

## 2500             0           0           0           0           0           0           0

##       Pixel_695 Pixel_696 Pixel_697 Pixel_698 Pixel_699 Pixel_700 Pixel_701

## 2496             0           0           0           0           0           0           0

## 2497             0           0           0           0           0           0           0

## 2498             0           0           0           0           0           0           0
```

```
## 2499            0          0          0          0          0          0          0

## 2500            0          0          0          0          0          0          0

##      Pixel_702 Pixel_703 Pixel_704 Pixel_705 Pixel_706 Pixel_707 Pixel_708

## 2496            0          0          0          0          0          0          0

## 2497            0          0          0          0          0          0          0

## 2498            0          0          0          0          0          0          0

## 2499            0          0          0          0          0          0          0

## 2500            0          0          0          0          0          0          0

##      Pixel_709 Pixel_710 Pixel_711 Pixel_712 Pixel_713 Pixel_714 Pixel_715

## 2496            0          0          0          0          0          0          0

## 2497            0          0          0          0          0          0          0

## 2498            0          0          0          0          0          0          0

## 2499            0          0          0          0          0          0          0

## 2500            0          0          0          0          0          0          0

##      Pixel_716 Pixel_717 Pixel_718 Pixel_719 Pixel_720 Pixel_721 Pixel_722

## 2496            0          0          0          0          0          0          0

## 2497           22        252        208          0          0          0          0

## 2498            0          0          0          0          0          0          0

## 2499            0          0          0          0          0          0          0

## 2500            0          0          0          0          0          0          0

##      Pixel_723 Pixel_724 Pixel_725 Pixel_726 Pixel_727 Pixel_728 Pixel_729

## 2496            0          0          0          0          0          0          0

## 2497            0          0          0          0          0          0          0

## 2498            0          0          0          0          0          0          0

## 2499            0          0          0          0          0          0          0

## 2500            0          0          0          0          0          0          0
```

```
##      Pixel_730 Pixel_731 Pixel_732 Pixel_733 Pixel_734 Pixel_735 Pixel_736
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_737 Pixel_738 Pixel_739 Pixel_740 Pixel_741 Pixel_742 Pixel_743
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_744 Pixel_745 Pixel_746 Pixel_747 Pixel_748 Pixel_749 Pixel_750
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_751 Pixel_752 Pixel_753 Pixel_754 Pixel_755 Pixel_756 Pixel_757
## 2496         0         0         0         0         0         0         0
## 2497         0         0         0         0         0         0         0
## 2498         0         0         0         0         0         0         0
## 2499         0         0         0         0         0         0         0
## 2500         0         0         0         0         0         0         0
##      Pixel_758 Pixel_759 Pixel_760 Pixel_761 Pixel_762 Pixel_763 Pixel_764
## 2496         0         0         0         0         0         0         0
```

```
## 2497           0          0          0          0          0          0          0

## 2498           0          0          0          0          0          0          0

## 2499           0          0          0          0          0          0          0

## 2500           0          0          0          0          0          0          0

##      Pixel_765 Pixel_766 Pixel_767 Pixel_768 Pixel_769 Pixel_770 Pixel_771

## 2496           0          0          0          0          0          0          0

## 2497           0          0          0          0          0          0          0

## 2498           0          0          0          0          0          0          0

## 2499           0          0          0          0          0          0          0

## 2500           0          0          0          0          0          0          0

##      Pixel_772 Pixel_773 Pixel_774 Pixel_775 Pixel_776 Pixel_777 Pixel_778

## 2496           0          0          0          0          0          0          0

## 2497           0          0          0          0          0          0          0

## 2498           0          0          0          0          0          0          0

## 2499           0          0          0          0          0          0          0

## 2500           0          0          0          0          0          0          0

##      Pixel_779 Pixel_780 Pixel_781 Pixel_782 Pixel_783 Pixel_784

## 2496           0          0          0          0          0          0

## 2497           0          0          0          0          0          0

## 2498           0          0          0          0          0          0

## 2499           0          0          0          0          0          0

## 2500           0          0          0          0          0          0
```

```r
#classifying the numbers in the digits column as either even or odd

even_odd = ifelse(test = pixel[, 1] %% 2 == 0, yes = "even", no = "odd")



#we also do another classification using 0 for even numbers and 1 otherwise
```

```
#this might be useful in data modelling

zero_one = ifelse(test = pixel[, 1] %% 2 == 0, yes = 0, no = 1)



#the formula above has classified the digits correctly

#see below

table(pixel[, 1], even_odd)
```

```
##     even_odd

##      even odd

##   0  237   0

##   1    0 244

##   2  243   0

##   3    0 241

##   4  275   0

##   5    0 232

##   6  247   0

##   7    0 273

##   8  247   0

##   9    0 261
```

```
table(pixel[, 1], zero_one)
```

```
##     zero_one

##        0   1

##   0  237   0

##   1    0 244

##   2  243   0

##   3    0 241
```

```
##   4 275   0
```

```
##   5   0 232
```

```
##   6 247   0
```

```
##   7   0 273
```

```
##   8 247   0
```

```
##   9   0 261
```

```
#we replace the Digit column in the orginal data frame

#the two columns above result in two new data frames being created

pixel_even_odd = data.frame(Digits = even_odd, pixel[, -1])

pixel_zero_one = data.frame(Digits = zero_one, pixel[, -1])



#summary statistics of a sample of the predictor variables

#seems to suggest that the variables are populated with zeros

summary(pixel[, c(2:7)])
```

```
##      Pixel_1      Pixel_2      Pixel_3      Pixel_4      Pixel_5      Pixel_6
```

```
##  Min.   :0   Min.   :0   Min.   :0   Min.   :0   Min.   :0   Min.   :0
```

```
##  1st Qu.:0   1st Qu.:0   1st Qu.:0   1st Qu.:0   1st Qu.:0   1st Qu.:0
```

```
##  Median :0   Median :0   Median :0   Median :0   Median :0   Median :0
```

```
##  Mean   :0   Mean   :0   Mean   :0   Mean   :0   Mean   :0   Mean   :0
```

```
##  3rd Qu.:0   3rd Qu.:0   3rd Qu.:0   3rd Qu.:0   3rd Qu.:0   3rd Qu.:0
```

```
##  Max.   :0   Max.   :0   Max.   :0   Max.   :0   Max.   :0   Max.   :0
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 3.5.1
```

```
ggplot(warpbreaks, aes(x=breaks)) +

  geom_histogram(bins=10) +

  facet_grid(wool ~ tension) +

  theme_classic()
```
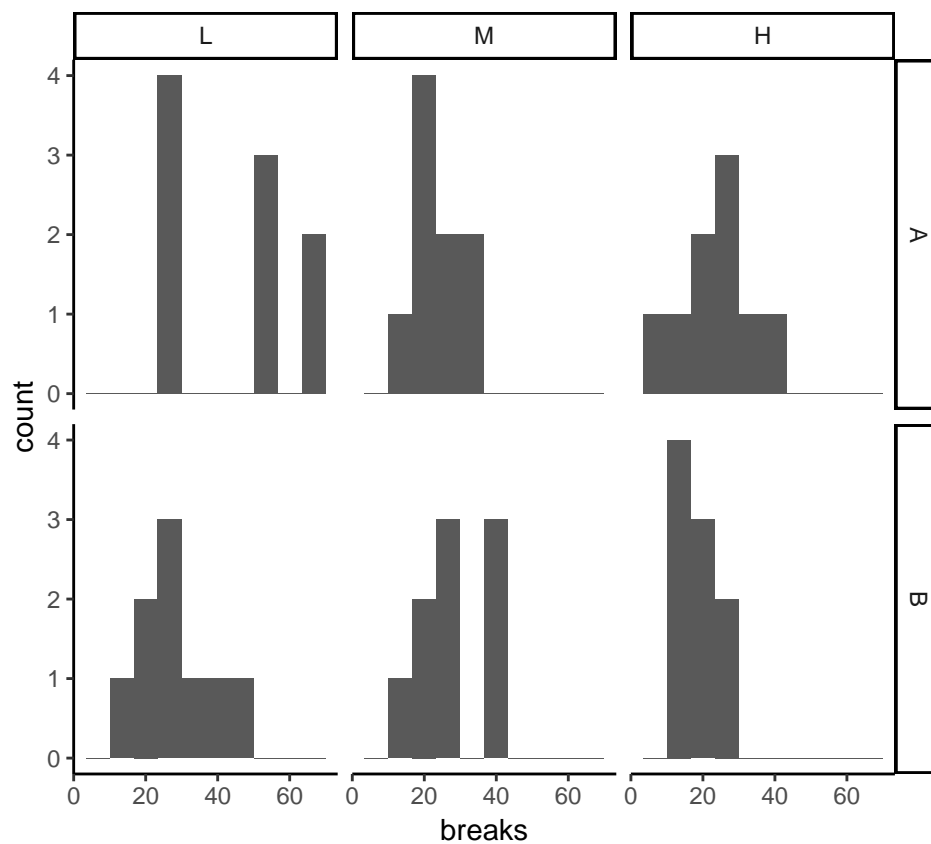


```
ggplot(warpbreaks, aes(y=breaks, x=tension, fill = wool)) +

  geom_boxplot() +

  theme_classic()
```
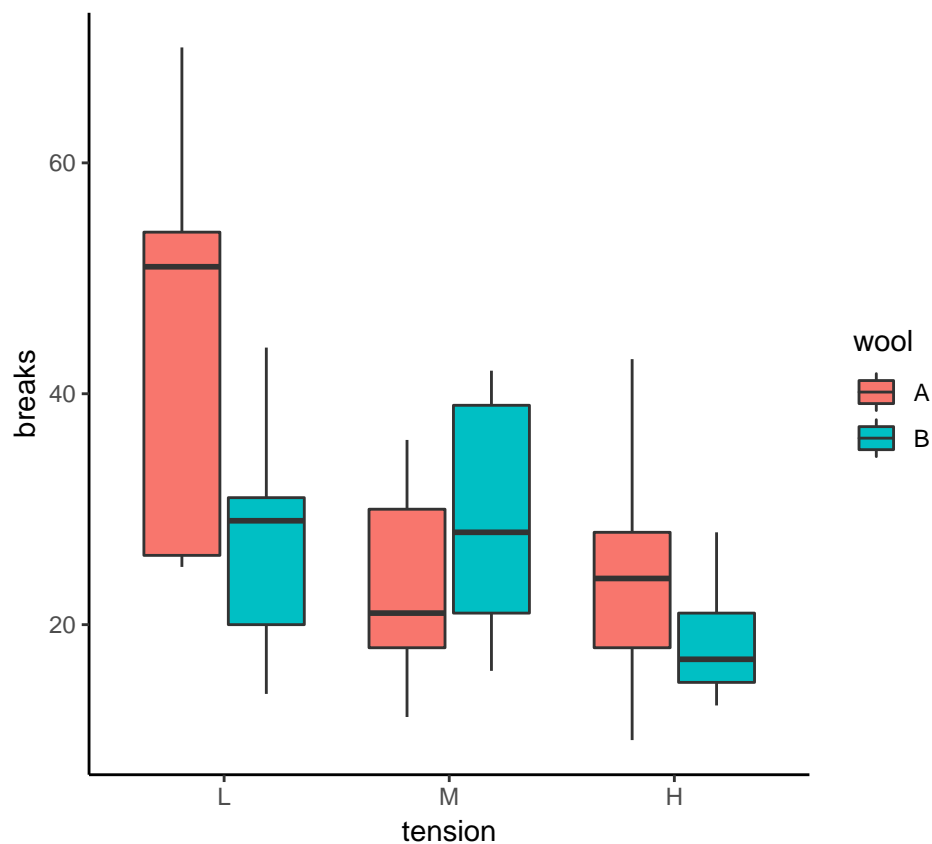
```
library(plyr)
```

```
## Warning: package 'plyr' was built under R version 3.5.1
```

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 3.5.1
```

```
##
```

```
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:plyr':
```

```
##
```

```
##      arrange, count, desc, failwith, id, mutate, rename, summarise,
```

```
##      summarize
```

```
## The following objects are masked from 'package:stats':
```

```
##

##      filter, lag

## The following objects are masked from 'package:base':

##

##      intersect, setdiff, setequal, union
```

```r
#counting the number of unique values in each coulumn

pixel[,-1] %>%

  summarise_all(n_distinct) %>%    #counting the number of unique values

  t() %>%                #transposing the vector

  head(n = 20)
```

```
##            [,1]

## Pixel_1    1

## Pixel_2    1

## Pixel_3    1

## Pixel_4    1

## Pixel_5    1

## Pixel_6    1

## Pixel_7    1

## Pixel_8    1

## Pixel_9    1

## Pixel_10   1

## Pixel_11   1

## Pixel_12   1

## Pixel_13   1

## Pixel_14   1
```

```
## Pixel_15    1

## Pixel_16    1

## Pixel_17    1

## Pixel_18    1

## Pixel_19    2

## Pixel_20    1
```

Data Pre-processing