Task 6

for Advanced Methods for Regression and Classification

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Contents

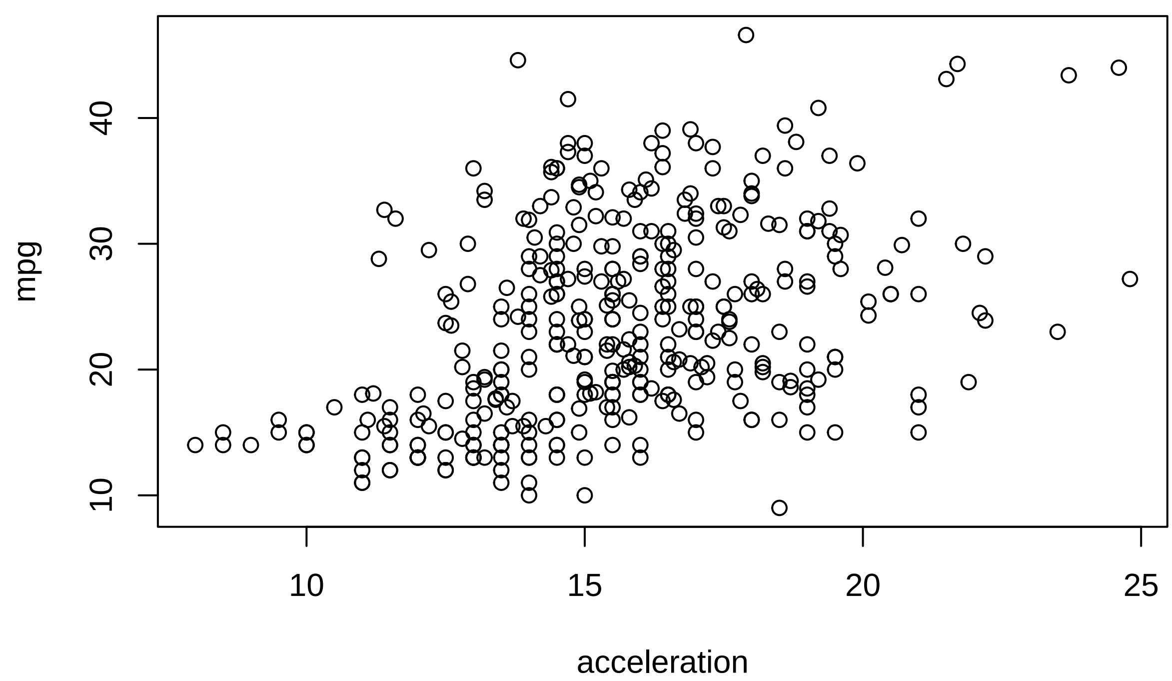
Regression on Splines

In this exercise we will see the different splines methods and how we can regress this data as non-linear.

```
library(ISLR)
library(splines)

data(Auto ,package="ISLR")

df <- Auto

str(df)
```

```
## 'data.frame':    392 obs. of  9 variables:
##  $ mpg         : num  18 15 18 16 17 15 14 14 14 15 ...
##  $ cylinders   : num  8 8 8 8 8 8 8 8 8 8 ...
##  $ displacement: num  307 350 318 304 302 429 454 440 455 390 ...
##  $ horsepower  : num  130 165 150 150 140 198 220 215 225 190 ...
##  $ weight      : num  3504 3693 3436 3433 3449 ...
##  $ acceleration: num  12 11.5 11 12 10.5 10 9 8.5 10 8.5 ...
##  $ year        : num  70 70 70 70 70 70 70 70 70 70 ...
##  $ origin      : num  1 1 1 1 1 1 1 1 1 1 ...
##  $ name        : Factor w/ 304 levels "amc ambassador brougham",..: 49 36 231 14 161 141 54 223 241
```

```r
plot(mpg~acceleration, data = df)
```



This scatter plot is showing non-linearity of those two attributes.

```r
df
```

```
##     mpg cylinders displacement horsepower weight acceleration year origin
## 1   18.0         8        307.0        130   3504         12.0   70      1
## 2   15.0         8        350.0        165   3693         11.5   70      1
## 3   18.0         8        318.0        150   3436         11.0   70      1
## 4   16.0         8        304.0        150   3433         12.0   70      1
## 5   17.0         8        302.0        140   3449         10.5   70      1
## 6   15.0         8        429.0        198   4341         10.0   70      1
## 7   14.0         8        454.0        220   4354          9.0   70      1
## 8   14.0         8        440.0        215   4312          8.5   70      1
## 9   14.0         8        455.0        225   4425         10.0   70      1
## 10  15.0         8        390.0        190   3850          8.5   70      1
## 11  15.0         8        383.0        170   3563         10.0   70      1
## 12  14.0         8        340.0        160   3609          8.0   70      1
## 13  15.0         8        400.0        150   3761          9.5   70      1
## 14  14.0         8        455.0        225   3086         10.0   70      1
## 15  24.0         4        113.0         95   2372         15.0   70      3
## 16  22.0         6        198.0         95   2833         15.5   70      1
## 17  18.0         6        199.0         97   2774         15.5   70      1
## 18  21.0         6        200.0         85   2587         16.0   70      1
## 19  27.0         4         97.0         88   2130         14.5   70      3
```

```
## 20  26.0         4        97.0         46  1835         20.5  70       2
## 21  25.0         4       110.0         87  2672         17.5  70       2
## 22  24.0         4       107.0         90  2430         14.5  70       2
## 23  25.0         4       104.0         95  2375         17.5  70       2
## 24  26.0         4       121.0        113  2234         12.5  70       2
## 25  21.0         6       199.0         90  2648         15.0  70       1
## 26  10.0         8       360.0        215  4615         14.0  70       1
## 27  10.0         8       307.0        200  4376         15.0  70       1
## 28  11.0         8       318.0        210  4382         13.5  70       1
## 29   9.0         8       304.0        193  4732         18.5  70       1
## 30  27.0         4        97.0         88  2130         14.5  71       3
## 31  28.0         4       140.0         90  2264         15.5  71       1
## 32  25.0         4       113.0         95  2228         14.0  71       3
## 34  19.0         6       232.0        100  2634         13.0  71       1
## 35  16.0         6       225.0        105  3439         15.5  71       1
## 36  17.0         6       250.0        100  3329         15.5  71       1
## 37  19.0         6       250.0         88  3302         15.5  71       1
## 38  18.0         6       232.0        100  3288         15.5  71       1
## 39  14.0         8       350.0        165  4209         12.0  71       1
## 40  14.0         8       400.0        175  4464         11.5  71       1
## 41  14.0         8       351.0        153  4154         13.5  71       1
## 42  14.0         8       318.0        150  4096         13.0  71       1
## 43  12.0         8       383.0        180  4955         11.5  71       1
## 44  13.0         8       400.0        170  4746         12.0  71       1
## 45  13.0         8       400.0        175  5140         12.0  71       1
## 46  18.0         6       258.0        110  2962         13.5  71       1
## 47  22.0         4       140.0         72  2408         19.0  71       1
## 48  19.0         6       250.0        100  3282         15.0  71       1
## 49  18.0         6       250.0         88  3139         14.5  71       1
## 50  23.0         4       122.0         86  2220         14.0  71       1
## 51  28.0         4       116.0         90  2123         14.0  71       2
## 52  30.0         4        79.0         70  2074         19.5  71       2
## 53  30.0         4        88.0         76  2065         14.5  71       2
## 54  31.0         4        71.0         65  1773         19.0  71       3
## 55  35.0         4        72.0         69  1613         18.0  71       3
## 56  27.0         4        97.0         60  1834         19.0  71       2
## 57  26.0         4        91.0         70  1955         20.5  71       1
## 58  24.0         4       113.0         95  2278         15.5  72       3
## 59  25.0         4        97.5         80  2126         17.0  72       1
## 60  23.0         4        97.0         54  2254         23.5  72       2
## 61  20.0         4       140.0         90  2408         19.5  72       1
## 62  21.0         4       122.0         86  2226         16.5  72       1
## 63  13.0         8       350.0        165  4274         12.0  72       1
## 64  14.0         8       400.0        175  4385         12.0  72       1
## 65  15.0         8       318.0        150  4135         13.5  72       1
## 66  14.0         8       351.0        153  4129         13.0  72       1
## 67  17.0         8       304.0        150  3672         11.5  72       1
## 68  11.0         8       429.0        208  4633         11.0  72       1
## 69  13.0         8       350.0        155  4502         13.5  72       1
## 70  12.0         8       350.0        160  4456         13.5  72       1
## 71  13.0         8       400.0        190  4422         12.5  72       1
## 72  19.0         3        70.0         97  2330         13.5  72       3
## 73  15.0         8       304.0        150  3892         12.5  72       1
## 74  13.0         8       307.0        130  4098         14.0  72       1
```

```
## 75  13.0           8          302.0        140   4294          16.0   72       1
## 76  14.0           8          318.0        150   4077          14.0   72       1
## 77  18.0           4          121.0        112   2933          14.5   72       2
## 78  22.0           4          121.0         76   2511          18.0   72       2
## 79  21.0           4          120.0         87   2979          19.5   72       2
## 80  26.0           4           96.0         69   2189          18.0   72       2
## 81  22.0           4          122.0         86   2395          16.0   72       1
## 82  28.0           4           97.0         92   2288          17.0   72       3
## 83  23.0           4          120.0         97   2506          14.5   72       3
## 84  28.0           4           98.0         80   2164          15.0   72       1
## 85  27.0           4           97.0         88   2100          16.5   72       3
## 86  13.0           8          350.0        175   4100          13.0   73       1
## 87  14.0           8          304.0        150   3672          11.5   73       1
## 88  13.0           8          350.0        145   3988          13.0   73       1
## 89  14.0           8          302.0        137   4042          14.5   73       1
## 90  15.0           8          318.0        150   3777          12.5   73       1
## 91  12.0           8          429.0        198   4952          11.5   73       1
## 92  13.0           8          400.0        150   4464          12.0   73       1
## 93  13.0           8          351.0        158   4363          13.0   73       1
## 94  14.0           8          318.0        150   4237          14.5   73       1
## 95  13.0           8          440.0        215   4735          11.0   73       1
## 96  12.0           8          455.0        225   4951          11.0   73       1
## 97  13.0           8          360.0        175   3821          11.0   73       1
## 98  18.0           6          225.0        105   3121          16.5   73       1
## 99  16.0           6          250.0        100   3278          18.0   73       1
## 100 18.0           6          232.0        100   2945          16.0   73       1
## 101 18.0           6          250.0         88   3021          16.5   73       1
## 102 23.0           6          198.0         95   2904          16.0   73       1
## 103 26.0           4           97.0         46   1950          21.0   73       2
## 104 11.0           8          400.0        150   4997          14.0   73       1
## 105 12.0           8          400.0        167   4906          12.5   73       1
## 106 13.0           8          360.0        170   4654          13.0   73       1
## 107 12.0           8          350.0        180   4499          12.5   73       1
## 108 18.0           6          232.0        100   2789          15.0   73       1
## 109 20.0           4           97.0         88   2279          19.0   73       3
## 110 21.0           4          140.0         72   2401          19.5   73       1
## 111 22.0           4          108.0         94   2379          16.5   73       3
## 112 18.0           3           70.0         90   2124          13.5   73       3
## 113 19.0           4          122.0         85   2310          18.5   73       1
## 114 21.0           6          155.0        107   2472          14.0   73       1
## 115 26.0           4           98.0         90   2265          15.5   73       2
## 116 15.0           8          350.0        145   4082          13.0   73       1
## 117 16.0           8          400.0        230   4278           9.5   73       1
## 118 29.0           4           68.0         49   1867          19.5   73       2
## 119 24.0           4          116.0         75   2158          15.5   73       2
## 120 20.0           4          114.0         91   2582          14.0   73       2
## 121 19.0           4          121.0        112   2868          15.5   73       2
## 122 15.0           8          318.0        150   3399          11.0   73       1
## 123 24.0           4          121.0        110   2660          14.0   73       2
## 124 20.0           6          156.0        122   2807          13.5   73       3
## 125 11.0           8          350.0        180   3664          11.0   73       1
## 126 20.0           6          198.0         95   3102          16.5   74       1
## 128 19.0           6          232.0        100   2901          16.0   74       1
## 129 15.0           6          250.0        100   3336          17.0   74       1
```

```
## 130 31.0         4         79.0        67   1950         19.0   74      3
## 131 26.0         4        122.0        80   2451         16.5   74      1
## 132 32.0         4         71.0        65   1836         21.0   74      3
## 133 25.0         4        140.0        75   2542         17.0   74      1
## 134 16.0         6        250.0       100   3781         17.0   74      1
## 135 16.0         6        258.0       110   3632         18.0   74      1
## 136 18.0         6        225.0       105   3613         16.5   74      1
## 137 16.0         8        302.0       140   4141         14.0   74      1
## 138 13.0         8        350.0       150   4699         14.5   74      1
## 139 14.0         8        318.0       150   4457         13.5   74      1
## 140 14.0         8        302.0       140   4638         16.0   74      1
## 141 14.0         8        304.0       150   4257         15.5   74      1
## 142 29.0         4         98.0        83   2219         16.5   74      2
## 143 26.0         4         79.0        67   1963         15.5   74      2
## 144 26.0         4         97.0        78   2300         14.5   74      2
## 145 31.0         4         76.0        52   1649         16.5   74      3
## 146 32.0         4         83.0        61   2003         19.0   74      3
## 147 28.0         4         90.0        75   2125         14.5   74      1
## 148 24.0         4         90.0        75   2108         15.5   74      2
## 149 26.0         4        116.0        75   2246         14.0   74      2
## 150 24.0         4        120.0        97   2489         15.0   74      3
## 151 26.0         4        108.0        93   2391         15.5   74      3
## 152 31.0         4         79.0        67   2000         16.0   74      2
## 153 19.0         6        225.0        95   3264         16.0   75      1
## 154 18.0         6        250.0       105   3459         16.0   75      1
## 155 15.0         6        250.0        72   3432         21.0   75      1
## 156 15.0         6        250.0        72   3158         19.5   75      1
## 157 16.0         8        400.0       170   4668         11.5   75      1
## 158 15.0         8        350.0       145   4440         14.0   75      1
## 159 16.0         8        318.0       150   4498         14.5   75      1
## 160 14.0         8        351.0       148   4657         13.5   75      1
## 161 17.0         6        231.0       110   3907         21.0   75      1
## 162 16.0         6        250.0       105   3897         18.5   75      1
## 163 15.0         6        258.0       110   3730         19.0   75      1
## 164 18.0         6        225.0        95   3785         19.0   75      1
## 165 21.0         6        231.0       110   3039         15.0   75      1
## 166 20.0         8        262.0       110   3221         13.5   75      1
## 167 13.0         8        302.0       129   3169         12.0   75      1
## 168 29.0         4         97.0        75   2171         16.0   75      3
## 169 23.0         4        140.0        83   2639         17.0   75      1
## 170 20.0         6        232.0       100   2914         16.0   75      1
## 171 23.0         4        140.0        78   2592         18.5   75      1
## 172 24.0         4        134.0        96   2702         13.5   75      3
## 173 25.0         4         90.0        71   2223         16.5   75      2
## 174 24.0         4        119.0        97   2545         17.0   75      3
## 175 18.0         6        171.0        97   2984         14.5   75      1
## 176 29.0         4         90.0        70   1937         14.0   75      2
## 177 19.0         6        232.0        90   3211         17.0   75      1
## 178 23.0         4        115.0        95   2694         15.0   75      2
## 179 23.0         4        120.0        88   2957         17.0   75      2
## 180 22.0         4        121.0        98   2945         14.5   75      2
## 181 25.0         4        121.0       115   2671         13.5   75      2
## 182 33.0         4         91.0        53   1795         17.5   75      3
## 183 28.0         4        107.0        86   2464         15.5   76      2
```

```
## 184 25.0         4       116.0         81  2220          16.9  76       2
## 185 25.0         4       140.0         92  2572          14.9  76       1
## 186 26.0         4        98.0         79  2255          17.7  76       1
## 187 27.0         4       101.0         83  2202          15.3  76       2
## 188 17.5         8       305.0        140  4215          13.0  76       1
## 189 16.0         8       318.0        150  4190          13.0  76       1
## 190 15.5         8       304.0        120  3962          13.9  76       1
## 191 14.5         8       351.0        152  4215          12.8  76       1
## 192 22.0         6       225.0        100  3233          15.4  76       1
## 193 22.0         6       250.0        105  3353          14.5  76       1
## 194 24.0         6       200.0         81  3012          17.6  76       1
## 195 22.5         6       232.0         90  3085          17.6  76       1
## 196 29.0         4        85.0         52  2035          22.2  76       1
## 197 24.5         4        98.0         60  2164          22.1  76       1
## 198 29.0         4        90.0         70  1937          14.2  76       2
## 199 33.0         4        91.0         53  1795          17.4  76       3
## 200 20.0         6       225.0        100  3651          17.7  76       1
## 201 18.0         6       250.0         78  3574          21.0  76       1
## 202 18.5         6       250.0        110  3645          16.2  76       1
## 203 17.5         6       258.0         95  3193          17.8  76       1
## 204 29.5         4        97.0         71  1825          12.2  76       2
## 205 32.0         4        85.0         70  1990          17.0  76       3
## 206 28.0         4        97.0         75  2155          16.4  76       3
## 207 26.5         4       140.0         72  2565          13.6  76       1
## 208 20.0         4       130.0        102  3150          15.7  76       2
## 209 13.0         8       318.0        150  3940          13.2  76       1
## 210 19.0         4       120.0         88  3270          21.9  76       2
## 211 19.0         6       156.0        108  2930          15.5  76       3
## 212 16.5         6       168.0        120  3820          16.7  76       2
## 213 16.5         8       350.0        180  4380          12.1  76       1
## 214 13.0         8       350.0        145  4055          12.0  76       1
## 215 13.0         8       302.0        130  3870          15.0  76       1
## 216 13.0         8       318.0        150  3755          14.0  76       1
## 217 31.5         4        98.0         68  2045          18.5  77       3
## 218 30.0         4       111.0         80  2155          14.8  77       1
## 219 36.0         4        79.0         58  1825          18.6  77       2
## 220 25.5         4       122.0         96  2300          15.5  77       1
## 221 33.5         4        85.0         70  1945          16.8  77       3
## 222 17.5         8       305.0        145  3880          12.5  77       1
## 223 17.0         8       260.0        110  4060          19.0  77       1
## 224 15.5         8       318.0        145  4140          13.7  77       1
## 225 15.0         8       302.0        130  4295          14.9  77       1
## 226 17.5         6       250.0        110  3520          16.4  77       1
## 227 20.5         6       231.0        105  3425          16.9  77       1
## 228 19.0         6       225.0        100  3630          17.7  77       1
## 229 18.5         6       250.0         98  3525          19.0  77       1
## 230 16.0         8       400.0        180  4220          11.1  77       1
## 231 15.5         8       350.0        170  4165          11.4  77       1
## 232 15.5         8       400.0        190  4325          12.2  77       1
## 233 16.0         8       351.0        149  4335          14.5  77       1
## 234 29.0         4        97.0         78  1940          14.5  77       2
## 235 24.5         4       151.0         88  2740          16.0  77       1
## 236 26.0         4        97.0         75  2265          18.2  77       3
## 237 25.5         4       140.0         89  2755          15.8  77       1
```

```
## 238 30.5         4          98.0          63   2051          17.0   77        1
## 239 33.5         4          98.0          83   2075          15.9   77        1
## 240 30.0         4          97.0          67   1985          16.4   77        3
## 241 30.5         4          97.0          78   2190          14.1   77        2
## 242 22.0         6         146.0          97   2815          14.5   77        3
## 243 21.5         4         121.0         110   2600          12.8   77        2
## 244 21.5         3          80.0         110   2720          13.5   77        3
## 245 43.1         4          90.0          48   1985          21.5   78        2
## 246 36.1         4          98.0          66   1800          14.4   78        1
## 247 32.8         4          78.0          52   1985          19.4   78        3
## 248 39.4         4          85.0          70   2070          18.6   78        3
## 249 36.1         4          91.0          60   1800          16.4   78        3
## 250 19.9         8         260.0         110   3365          15.5   78        1
## 251 19.4         8         318.0         140   3735          13.2   78        1
## 252 20.2         8         302.0         139   3570          12.8   78        1
## 253 19.2         6         231.0         105   3535          19.2   78        1
## 254 20.5         6         200.0          95   3155          18.2   78        1
## 255 20.2         6         200.0          85   2965          15.8   78        1
## 256 25.1         4         140.0          88   2720          15.4   78        1
## 257 20.5         6         225.0         100   3430          17.2   78        1
## 258 19.4         6         232.0          90   3210          17.2   78        1
## 259 20.6         6         231.0         105   3380          15.8   78        1
## 260 20.8         6         200.0          85   3070          16.7   78        1
## 261 18.6         6         225.0         110   3620          18.7   78        1
## 262 18.1         6         258.0         120   3410          15.1   78        1
## 263 19.2         8         305.0         145   3425          13.2   78        1
## 264 17.7         6         231.0         165   3445          13.4   78        1
## 265 18.1         8         302.0         139   3205          11.2   78        1
## 266 17.5         8         318.0         140   4080          13.7   78        1
## 267 30.0         4          98.0          68   2155          16.5   78        1
## 268 27.5         4         134.0          95   2560          14.2   78        3
## 269 27.2         4         119.0          97   2300          14.7   78        3
## 270 30.9         4         105.0          75   2230          14.5   78        1
## 271 21.1         4         134.0          95   2515          14.8   78        3
## 272 23.2         4         156.0         105   2745          16.7   78        1
## 273 23.8         4         151.0          85   2855          17.6   78        1
## 274 23.9         4         119.0          97   2405          14.9   78        3
## 275 20.3         5         131.0         103   2830          15.9   78        2
## 276 17.0         6         163.0         125   3140          13.6   78        2
## 277 21.6         4         121.0         115   2795          15.7   78        2
## 278 16.2         6         163.0         133   3410          15.8   78        2
## 279 31.5         4          89.0          71   1990          14.9   78        2
## 280 29.5         4          98.0          68   2135          16.6   78        3
## 281 21.5         6         231.0         115   3245          15.4   79        1
## 282 19.8         6         200.0          85   2990          18.2   79        1
## 283 22.3         4         140.0          88   2890          17.3   79        1
## 284 20.2         6         232.0          90   3265          18.2   79        1
## 285 20.6         6         225.0         110   3360          16.6   79        1
## 286 17.0         8         305.0         130   3840          15.4   79        1
## 287 17.6         8         302.0         129   3725          13.4   79        1
## 288 16.5         8         351.0         138   3955          13.2   79        1
## 289 18.2         8         318.0         135   3830          15.2   79        1
## 290 16.9         8         350.0         155   4360          14.9   79        1
## 291 15.5         8         351.0         142   4054          14.3   79        1
```

```
## 292 19.2          8         267.0         125   3605          15.0   79        1
## 293 18.5          8         360.0         150   3940          13.0   79        1
## 294 31.9          4          89.0          71   1925          14.0   79        2
## 295 34.1          4          86.0          65   1975          15.2   79        3
## 296 35.7          4          98.0          80   1915          14.4   79        1
## 297 27.4          4         121.0          80   2670          15.0   79        1
## 298 25.4          5         183.0          77   3530          20.1   79        2
## 299 23.0          8         350.0         125   3900          17.4   79        1
## 300 27.2          4         141.0          71   3190          24.8   79        2
## 301 23.9          8         260.0          90   3420          22.2   79        1
## 302 34.2          4         105.0          70   2200          13.2   79        1
## 303 34.5          4         105.0          70   2150          14.9   79        1
## 304 31.8          4          85.0          65   2020          19.2   79        3
## 305 37.3          4          91.0          69   2130          14.7   79        2
## 306 28.4          4         151.0          90   2670          16.0   79        1
## 307 28.8          6         173.0         115   2595          11.3   79        1
## 308 26.8          6         173.0         115   2700          12.9   79        1
## 309 33.5          4         151.0          90   2556          13.2   79        1
## 310 41.5          4          98.0          76   2144          14.7   80        2
## 311 38.1          4          89.0          60   1968          18.8   80        3
## 312 32.1          4          98.0          70   2120          15.5   80        1
## 313 37.2          4          86.0          65   2019          16.4   80        3
## 314 28.0          4         151.0          90   2678          16.5   80        1
## 315 26.4          4         140.0          88   2870          18.1   80        1
## 316 24.3          4         151.0          90   3003          20.1   80        1
## 317 19.1          6         225.0          90   3381          18.7   80        1
## 318 34.3          4          97.0          78   2188          15.8   80        2
## 319 29.8          4         134.0          90   2711          15.5   80        3
## 320 31.3          4         120.0          75   2542          17.5   80        3
## 321 37.0          4         119.0          92   2434          15.0   80        3
## 322 32.2          4         108.0          75   2265          15.2   80        3
## 323 46.6          4          86.0          65   2110          17.9   80        3
## 324 27.9          4         156.0         105   2800          14.4   80        1
## 325 40.8          4          85.0          65   2110          19.2   80        3
## 326 44.3          4          90.0          48   2085          21.7   80        2
## 327 43.4          4          90.0          48   2335          23.7   80        2
## 328 36.4          5         121.0          67   2950          19.9   80        2
## 329 30.0          4         146.0          67   3250          21.8   80        2
## 330 44.6          4          91.0          67   1850          13.8   80        3
## 332 33.8          4          97.0          67   2145          18.0   80        3
## 333 29.8          4          89.0          62   1845          15.3   80        2
## 334 32.7          6         168.0         132   2910          11.4   80        3
## 335 23.7          3          70.0         100   2420          12.5   80        3
## 336 35.0          4         122.0          88   2500          15.1   80        2
## 338 32.4          4         107.0          72   2290          17.0   80        3
## 339 27.2          4         135.0          84   2490          15.7   81        1
## 340 26.6          4         151.0          84   2635          16.4   81        1
## 341 25.8          4         156.0          92   2620          14.4   81        1
## 342 23.5          6         173.0         110   2725          12.6   81        1
## 343 30.0          4         135.0          84   2385          12.9   81        1
## 344 39.1          4          79.0          58   1755          16.9   81        3
## 345 39.0          4          86.0          64   1875          16.4   81        1
## 346 35.1          4          81.0          60   1760          16.1   81        3
## 347 32.3          4          97.0          67   2065          17.8   81        3
```

```
## 348 37.0         4         85.0         65   1975         19.4   81       3
## 349 37.7         4         89.0         62   2050         17.3   81       3
## 350 34.1         4         91.0         68   1985         16.0   81       3
## 351 34.7         4        105.0         63   2215         14.9   81       1
## 352 34.4         4         98.0         65   2045         16.2   81       1
## 353 29.9         4         98.0         65   2380         20.7   81       1
## 354 33.0         4        105.0         74   2190         14.2   81       2
## 356 33.7         4        107.0         75   2210         14.4   81       3
## 357 32.4         4        108.0         75   2350         16.8   81       3
## 358 32.9         4        119.0        100   2615         14.8   81       3
## 359 31.6         4        120.0         74   2635         18.3   81       3
## 360 28.1         4        141.0         80   3230         20.4   81       2
## 361 30.7         6        145.0         76   3160         19.6   81       2
## 362 25.4         6        168.0        116   2900         12.6   81       3
## 363 24.2         6        146.0        120   2930         13.8   81       3
## 364 22.4         6        231.0        110   3415         15.8   81       1
## 365 26.6         8        350.0        105   3725         19.0   81       1
## 366 20.2         6        200.0         88   3060         17.1   81       1
## 367 17.6         6        225.0         85   3465         16.6   81       1
## 368 28.0         4        112.0         88   2605         19.6   82       1
## 369 27.0         4        112.0         88   2640         18.6   82       1
## 370 34.0         4        112.0         88   2395         18.0   82       1
## 371 31.0         4        112.0         85   2575         16.2   82       1
## 372 29.0         4        135.0         84   2525         16.0   82       1
## 373 27.0         4        151.0         90   2735         18.0   82       1
## 374 24.0         4        140.0         92   2865         16.4   82       1
## 375 36.0         4        105.0         74   1980         15.3   82       2
## 376 37.0         4         91.0         68   2025         18.2   82       3
## 377 31.0         4         91.0         68   1970         17.6   82       3
## 378 38.0         4        105.0         63   2125         14.7   82       1
## 379 36.0         4         98.0         70   2125         17.3   82       1
## 380 36.0         4        120.0         88   2160         14.5   82       3
## 381 36.0         4        107.0         75   2205         14.5   82       3
## 382 34.0         4        108.0         70   2245         16.9   82       3
## 383 38.0         4         91.0         67   1965         15.0   82       3
## 384 32.0         4         91.0         67   1965         15.7   82       3
## 385 38.0         4         91.0         67   1995         16.2   82       3
## 386 25.0         6        181.0        110   2945         16.4   82       1
## 387 38.0         6        262.0         85   3015         17.0   82       1
## 388 26.0         4        156.0         92   2585         14.5   82       1
## 389 22.0         6        232.0        112   2835         14.7   82       1
## 390 32.0         4        144.0         96   2665         13.9   82       3
## 391 36.0         4        135.0         84   2370         13.0   82       1
## 392 27.0         4        151.0         90   2950         17.3   82       1
## 393 27.0         4        140.0         86   2790         15.6   82       1
## 394 44.0         4         97.0         52   2130         24.6   82       2
## 395 32.0         4        135.0         84   2295         11.6   82       1
## 396 28.0         4        120.0         79   2625         18.6   82       1
## 397 31.0         4        119.0         82   2720         19.4   82       1
##                                     name
## 1              chevrolet chevelle malibu
## 2                      buick skylark 320
## 3                     plymouth satellite
## 4                          amc rebel sst
```

```
## 5                          ford torino
## 6                     ford galaxie 500
## 7                     chevrolet impala
## 8                    plymouth fury iii
## 9                     pontiac catalina
## 10                  amc ambassador dpl
## 11                 dodge challenger se
## 12                  plymouth 'cuda 340
## 13               chevrolet monte carlo
## 14             buick estate wagon (sw)
## 15               toyota corona mark ii
## 16                     plymouth duster
## 17                          amc hornet
## 18                       ford maverick
## 19                        datsun pl510
## 20        volkswagen 1131 deluxe sedan
## 21                         peugeot 504
## 22                         audi 100 ls
## 23                            saab 99e
## 24                            bmw 2002
## 25                         amc gremlin
## 26                           ford f250
## 27                           chevy c20
## 28                          dodge d200
## 29                            hi 1200d
## 30                        datsun pl510
## 31                 chevrolet vega 2300
## 32                       toyota corona
## 34                         amc gremlin
## 35           plymouth satellite custom
## 36           chevrolet chevelle malibu
## 37                     ford torino 500
## 38                         amc matador
## 39                    chevrolet impala
## 40           pontiac catalina brougham
## 41                    ford galaxie 500
## 42                   plymouth fury iii
## 43                   dodge monaco (sw)
## 44             ford country squire (sw)
## 45                 pontiac safari (sw)
## 46          amc hornet sportabout (sw)
## 47                 chevrolet vega (sw)
## 48                    pontiac firebird
## 49                        ford mustang
## 50                  mercury capri 2000
## 51                           opel 1900
## 52                         peugeot 304
## 53                           fiat 124b
## 54                 toyota corolla 1200
## 55                         datsun 1200
## 56                volkswagen model 111
## 57                    plymouth cricket
## 58               toyota corona hardtop
## 59                  dodge colt hardtop
```

```
## 60                    volkswagen type 3
## 61                       chevrolet vega
## 62                  ford pinto runabout
## 63                     chevrolet impala
## 64                     pontiac catalina
## 65                    plymouth fury iii
## 66                     ford galaxie 500
## 67                   amc ambassador sst
## 68                      mercury marquis
## 69                 buick lesabre custom
## 70           oldsmobile delta 88 royale
## 71               chrysler newport royal
## 72                      mazda rx2 coupe
## 73                     amc matador (sw)
## 74     chevrolet chevelle concours (sw)
## 75                ford gran torino (sw)
## 76       plymouth satellite custom (sw)
## 77                      volvo 145e (sw)
## 78                  volkswagen 411 (sw)
## 79                     peugeot 504 (sw)
## 80                      renault 12 (sw)
## 81                      ford pinto (sw)
## 82                      datsun 510 (sw)
## 83          toyouta corona mark ii (sw)
## 84                      dodge colt (sw)
## 85             toyota corolla 1600 (sw)
## 86                    buick century 350
## 87                          amc matador
## 88                     chevrolet malibu
## 89                     ford gran torino
## 90                 dodge coronet custom
## 91             mercury marquis brougham
## 92            chevrolet caprice classic
## 93                             ford ltd
## 94             plymouth fury gran sedan
## 95         chrysler new yorker brougham
## 96             buick electra 225 custom
## 97              amc ambassador brougham
## 98                     plymouth valiant
## 99                  chevrolet nova custom
## 100                          amc hornet
## 101                       ford maverick
## 102                     plymouth duster
## 103             volkswagen super beetle
## 104                    chevrolet impala
## 105                        ford country
## 106               plymouth custom suburb
## 107            oldsmobile vista cruiser
## 108                          amc gremlin
## 109                       toyota carina
## 110                      chevrolet vega
## 111                          datsun 610
## 112                           maxda rx3
## 113                          ford pinto
```

```
## 114                    mercury capri v6
## 115                fiat 124 sport coupe
## 116             chevrolet monte carlo s
## 117                  pontiac grand prix
## 118                            fiat 128
## 119                          opel manta
## 120                          audi 100ls
## 121                         volvo 144ea
## 122                   dodge dart custom
## 123                           saab 99le
## 124                      toyota mark ii
## 125                    oldsmobile omega
## 126                     plymouth duster
## 128                          amc hornet
## 129                      chevrolet nova
## 130                         datsun b210
## 131                          ford pinto
## 132                 toyota corolla 1200
## 133                      chevrolet vega
## 134   chevrolet chevelle malibu classic
## 135                         amc matador
## 136          plymouth satellite sebring
## 137                    ford gran torino
## 138            buick century luxus (sw)
## 139           dodge coronet custom (sw)
## 140               ford gran torino (sw)
## 141                    amc matador (sw)
## 142                            audi fox
## 143                   volkswagen dasher
## 144                          opel manta
## 145                       toyota corona
## 146                          datsun 710
## 147                          dodge colt
## 148                            fiat 128
## 149                         fiat 124 tc
## 150                         honda civic
## 151                              subaru
## 152                           fiat x1.9
## 153             plymouth valiant custom
## 154                      chevrolet nova
## 155                     mercury monarch
## 156                       ford maverick
## 157                    pontiac catalina
## 158                   chevrolet bel air
## 159                 plymouth grand fury
## 160                            ford ltd
## 161                       buick century
## 162           chevroelt chevelle malibu
## 163                         amc matador
## 164                       plymouth fury
## 165                       buick skyhawk
## 166                 chevrolet monza 2+2
## 167                     ford mustang ii
## 168                      toyota corolla
```

```
## 169                          ford pinto
## 170                         amc gremlin
## 171                       pontiac astro
## 172                       toyota corona
## 173                   volkswagen dasher
## 174                          datsun 710
## 175                          ford pinto
## 176                   volkswagen rabbit
## 177                           amc pacer
## 178                          audi 100ls
## 179                         peugeot 504
## 180                         volvo 244dl
## 181                           saab 99le
## 182                    honda civic cvcc
## 183                            fiat 131
## 184                           opel 1900
## 185                            capri ii
## 186                          dodge colt
## 187                        renault 12tl
## 188    chevrolet chevelle malibu classic
## 189             dodge coronet brougham
## 190                         amc matador
## 191                    ford gran torino
## 192                    plymouth valiant
## 193                      chevrolet nova
## 194                       ford maverick
## 195                          amc hornet
## 196                  chevrolet chevette
## 197                     chevrolet woody
## 198                           vw rabbit
## 199                         honda civic
## 200                      dodge aspen se
## 201                   ford granada ghia
## 202                  pontiac ventura sj
## 203                       amc pacer d/l
## 204                   volkswagen rabbit
## 205                        datsun b-210
## 206                      toyota corolla
## 207                          ford pinto
## 208                           volvo 245
## 209          plymouth volare premier v8
## 210                         peugeot 504
## 211                      toyota mark ii
## 212                  mercedes-benz 280s
## 213                    cadillac seville
## 214                           chevy c10
## 215                           ford f108
## 216                          dodge d100
## 217                   honda accord cvcc
## 218             buick opel isuzu deluxe
## 219                       renault 5 gtl
## 220                   plymouth arrow gs
## 221              datsun f-10 hatchback
## 222            chevrolet caprice classic
```

```
## 223          oldsmobile cutlass supreme
## 224               dodge monaco brougham
## 225             mercury cougar brougham
## 226                  chevrolet concours
## 227                       buick skylark
## 228              plymouth volare custom
## 229                        ford granada
## 230               pontiac grand prix lj
## 231        chevrolet monte carlo landau
## 232                    chrysler cordoba
## 233                    ford thunderbird
## 234            volkswagen rabbit custom
## 235               pontiac sunbird coupe
## 236             toyota corolla liftback
## 237                 ford mustang ii 2+2
## 238                  chevrolet chevette
## 239                      dodge colt m/m
## 240                           subaru dl
## 241                   volkswagen dasher
## 242                          datsun 810
## 243                            bmw 320i
## 244                          mazda rx-4
## 245     volkswagen rabbit custom diesel
## 246                         ford fiesta
## 247                    mazda glc deluxe
## 248                      datsun b210 gx
## 249                    honda civic cvcc
## 250   oldsmobile cutlass salon brougham
## 251                      dodge diplomat
## 252                 mercury monarch ghia
## 253                   pontiac phoenix lj
## 254                    chevrolet malibu
## 255                 ford fairmont (auto)
## 256                  ford fairmont (man)
## 257                     plymouth volare
## 258                         amc concord
## 259               buick century special
## 260                      mercury zephyr
## 261                         dodge aspen
## 262                     amc concord d/l
## 263        chevrolet monte carlo landau
## 264     buick regal sport coupe (turbo)
## 265                         ford futura
## 266                     dodge magnum xe
## 267                  chevrolet chevette
## 268                       toyota corona
## 269                          datsun 510
## 270                          dodge omni
## 271            toyota celica gt liftback
## 272                    plymouth sapporo
## 273              oldsmobile starfire sx
## 274                       datsun 200-sx
## 275                           audi 5000
## 276                         volvo 264gl
```

```
## 277                              saab 99gle
## 278                           peugeot 604sl
## 279                     volkswagen scirocco
## 280                         honda accord lx
## 281                       pontiac lemans v6
## 282                        mercury zephyr 6
## 283                         ford fairmont 4
## 284                        amc concord dl 6
## 285                           dodge aspen 6
## 286               chevrolet caprice classic
## 287                         ford ltd landau
## 288                   mercury grand marquis
## 289                         dodge st. regis
## 290                 buick estate wagon (sw)
## 291                ford country squire (sw)
## 292           chevrolet malibu classic (sw)
## 293 chrysler lebaron town @ country (sw)
## 294                        vw rabbit custom
## 295                        maxda glc deluxe
## 296             dodge colt hatchback custom
## 297                           amc spirit dl
## 298                      mercedes benz 300d
## 299                       cadillac eldorado
## 300                             peugeot 504
## 301       oldsmobile cutlass salon brougham
## 302                        plymouth horizon
## 303                    plymouth horizon tc3
## 304                              datsun 210
## 305                      fiat strada custom
## 306                   buick skylark limited
## 307                      chevrolet citation
## 308               oldsmobile omega brougham
## 309                         pontiac phoenix
## 310                               vw rabbit
## 311                   toyota corolla tercel
## 312                      chevrolet chevette
## 313                              datsun 310
## 314                      chevrolet citation
## 315                           ford fairmont
## 316                             amc concord
## 317                             dodge aspen
## 318                               audi 4000
## 319                  toyota corona liftback
## 320                               mazda 626
## 321                    datsun 510 hatchback
## 322                          toyota corolla
## 323                               mazda glc
## 324                              dodge colt
## 325                              datsun 210
## 326                    vw rabbit c (diesel)
## 327                      vw dasher (diesel)
## 328                     audi 5000s (diesel)
## 329                      mercedes-benz 240d
## 330                     honda civic 1500 gl
```

```
## 332                              subaru dl
## 333                       vokswagen rabbit
## 334                          datsun 280-zx
## 335                          mazda rx-7 gs
## 336                     triumph tr7 coupe
## 338                           honda accord
## 339                       plymouth reliant
## 340                          buick skylark
## 341                 dodge aries wagon (sw)
## 342                     chevrolet citation
## 343                       plymouth reliant
## 344                         toyota starlet
## 345                         plymouth champ
## 346                       honda civic 1300
## 347                                 subaru
## 348                         datsun 210 mpg
## 349                          toyota tercel
## 350                            mazda glc 4
## 351                     plymouth horizon 4
## 352                         ford escort 4w
## 353                         ford escort 2h
## 354                       volkswagen jetta
## 356                          honda prelude
## 357                         toyota corolla
## 358                           datsun 200sx
## 359                              mazda 626
## 360              peugeot 505s turbo diesel
## 361                           volvo diesel
## 362                        toyota cressida
## 363                      datsun 810 maxima
## 364                          buick century
## 365                 oldsmobile cutlass ls
## 366                        ford granada gl
## 367                 chrysler lebaron salon
## 368                     chevrolet cavalier
## 369               chevrolet cavalier wagon
## 370              chevrolet cavalier 2-door
## 371             pontiac j2000 se hatchback
## 372                         dodge aries se
## 373                        pontiac phoenix
## 374                   ford fairmont futura
## 375                    volkswagen rabbit l
## 376                     mazda glc custom l
## 377                       mazda glc custom
## 378                 plymouth horizon miser
## 379                         mercury lynx l
## 380                       nissan stanza xe
## 381                           honda accord
## 382                         toyota corolla
## 383                            honda civic
## 384                     honda civic (auto)
## 385                          datsun 310 gx
## 386                  buick century limited
## 387    oldsmobile cutlass ciera (diesel)
```

```
## 388           chrysler lebaron medallion
## 389                       ford granada l
## 390                     toyota celica gt
## 391                    dodge charger 2.2
## 392                     chevrolet camaro
## 393                      ford mustang gl
## 394                            vw pickup
## 395                        dodge rampage
## 396                          ford ranger
## 397                           chevy s-10
```

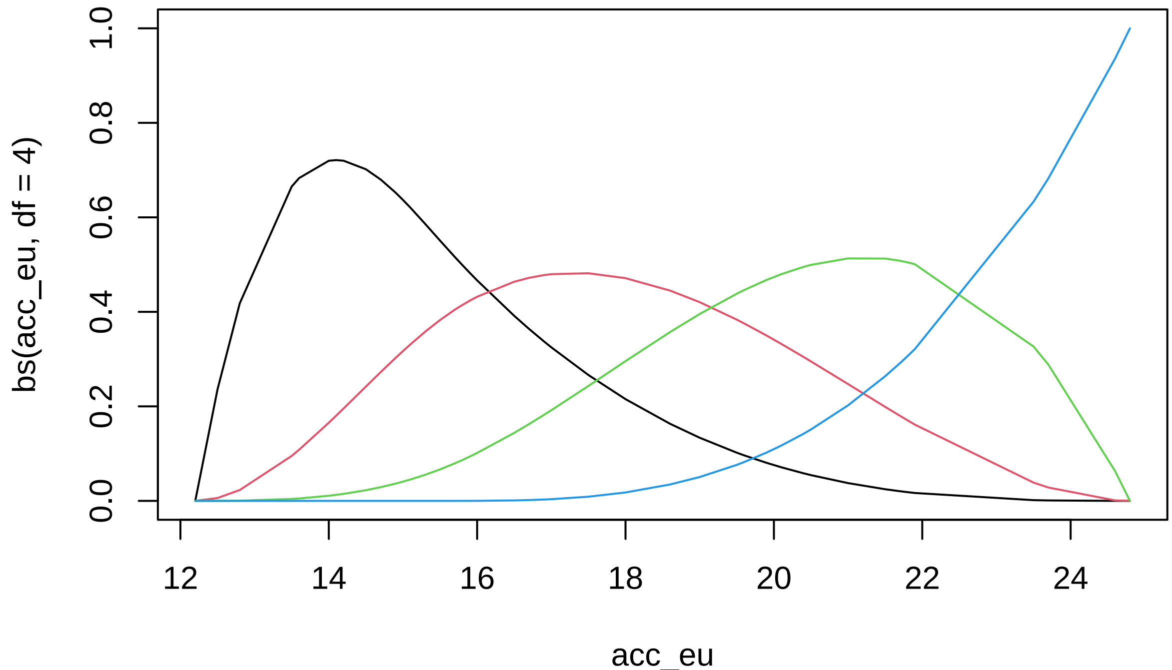
```
df <- df[order(df$acceleration),]
```

Splitting the data based on the origin group:

```
american <- subset(df, origin==1)
european <- subset(df, origin==2)
japan <- subset(df, origin==3)

mpg_eu <- european[ , which(names(european) %in% c("mpg"))]
acc_eu <- european[ , which(names(european) %in% c("acceleration"))]
mpg_us <- american[ , which(names(american) %in% c("mpg"))]
acc_us <- american[ , which(names(american) %in% c("acceleration"))]
mpg_jp <- japan[ , which(names(japan) %in% c("mpg"))]
acc_jp <- japan[ , which(names(japan) %in% c("acceleration"))]
```

Lets see the linear functions we create with B-splines with degrees of freedom = 4

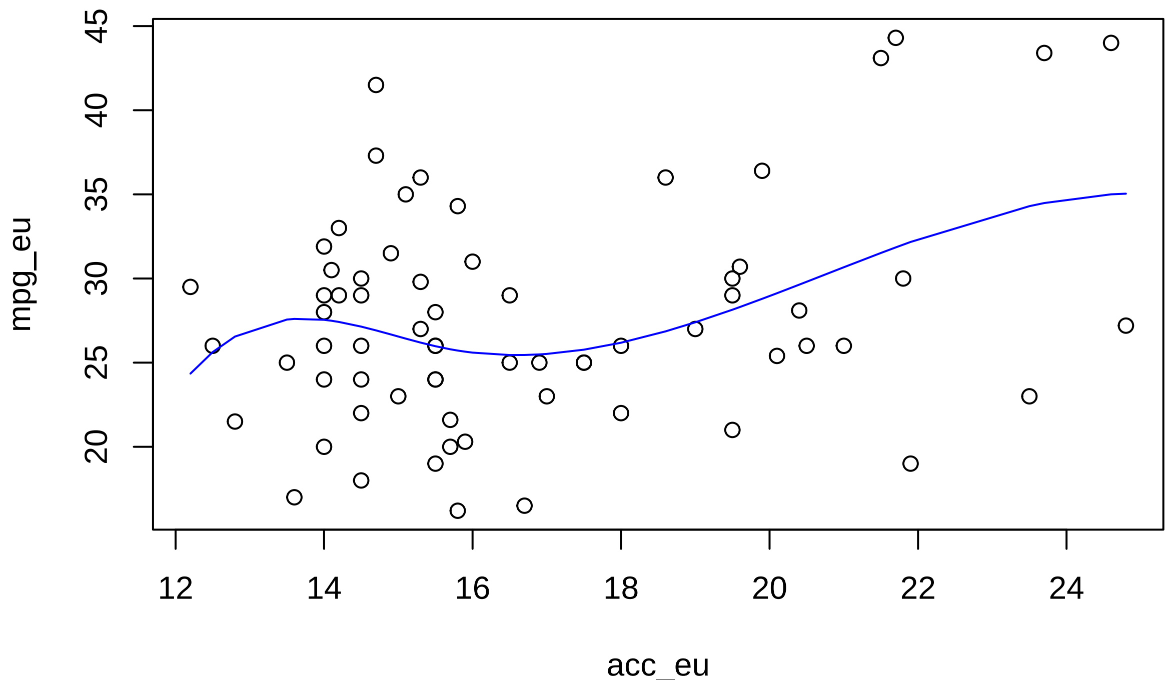
```
matplot(acc_eu, bs(acc_eu, df = 4), type="l",lty=1)
```



B-splines on:

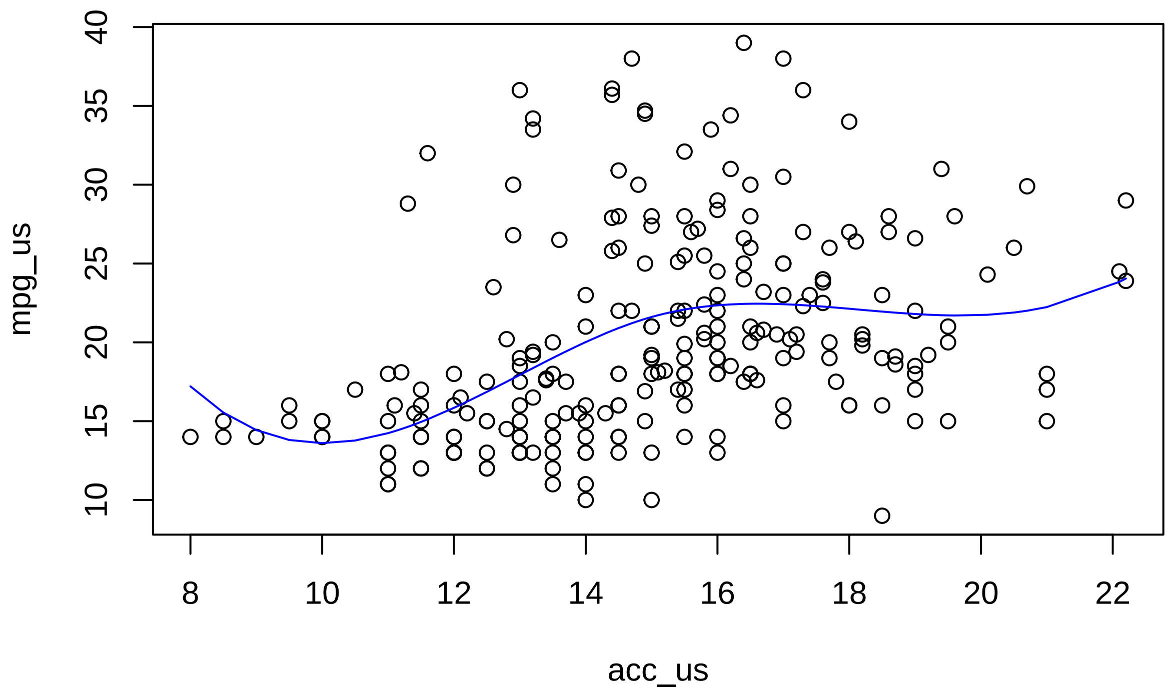
- European cars:

```
plot(acc_eu, mpg_eu)
lm1 <- lm(mpg_eu ~ bs(acc_eu, df=4))
lines(acc_eu,predict.lm(lm1,list(x=acc_eu)), col="blue")
```



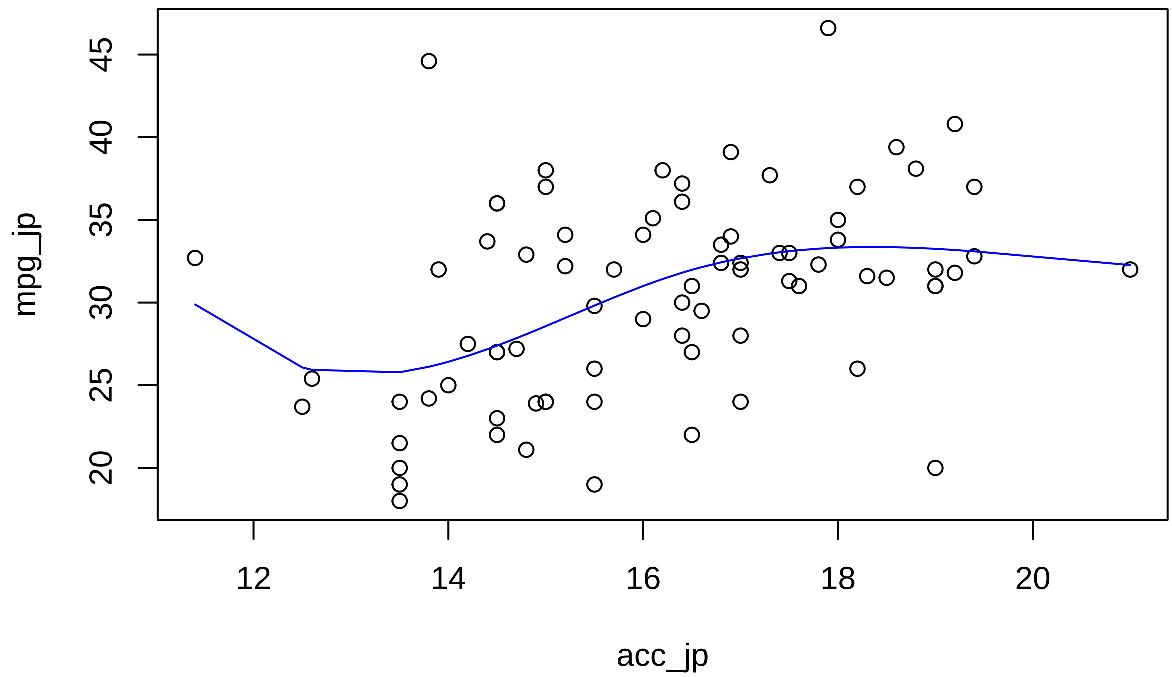
- United states cars:

```
plot(acc_us, mpg_us)
lm1 <- lm(mpg_us ~ bs(acc_us, df=4))
lines(acc_us,predict.lm(lm1,list(x=acc_us)), col="blue")
```



- Japanese cars:

```
plot(acc_jp, mpg_jp)
lm1 <- lm(mpg_jp ~ bs(acc_jp, df=4))
lines(acc_jp,predict.lm(lm1,list(x=acc_jp)), col="blue")
```

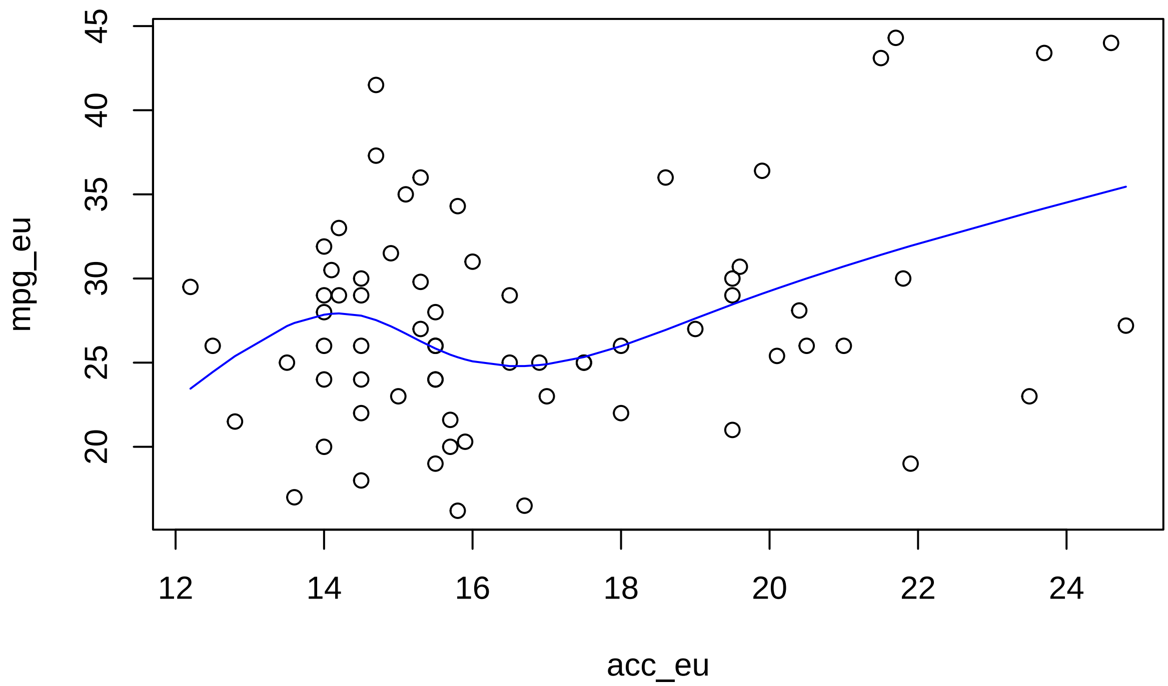


As we saw, we created separate linear regression models for each category of cars based on the 3 categories we have. As predicitve values we used acceleration and for dependent value we use the mpg. We can see this time we dont have singe straight line but a curved spline which tries to describe the best ways the given values.

Natural Cubic splines on:

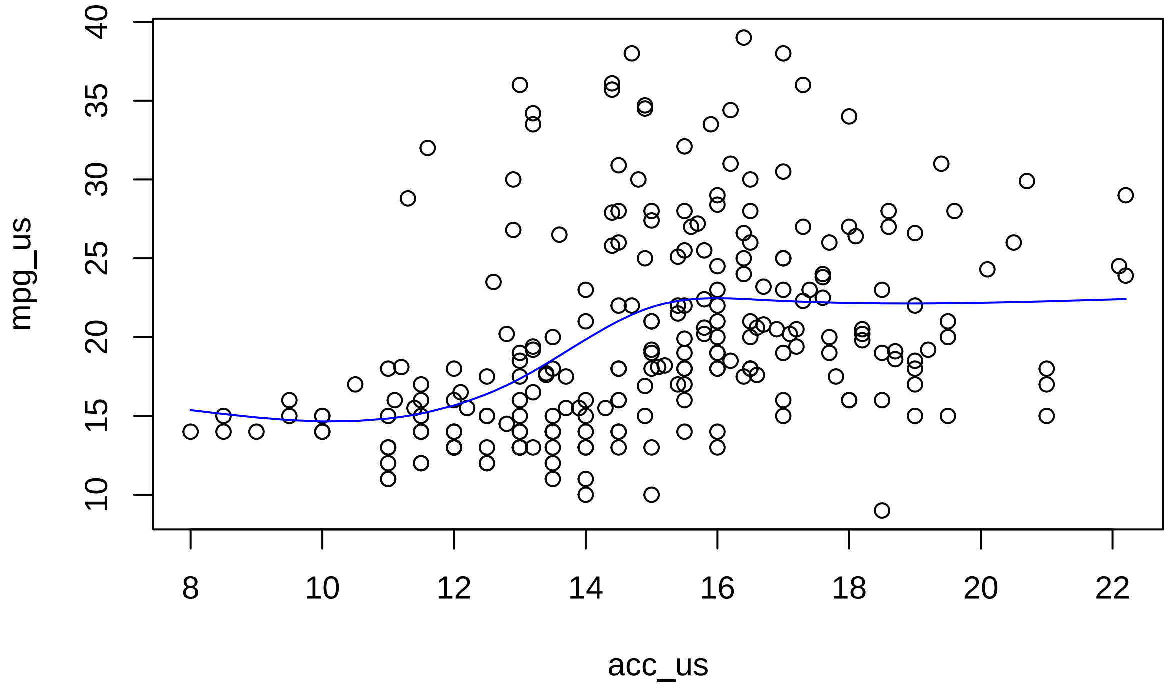
- European cars:

```
plot(acc_eu, mpg_eu)
lm1 <- lm(mpg_eu ~ ns(acc_eu, df=4))
lines(acc_eu,predict.lm(lm1,list(x=acc_eu)), col="blue")
```



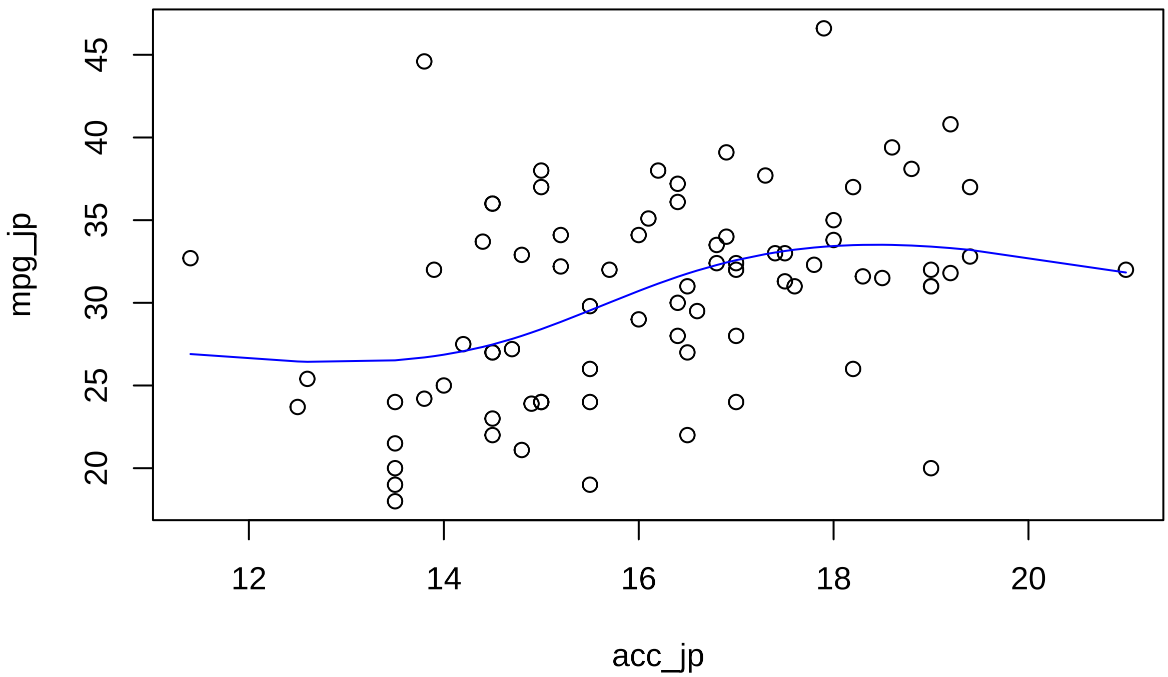
- United states cars:

```
plot(acc_us, mpg_us)
lm1 <- lm(mpg_us ~ ns(acc_us, df=4))
lines(acc_us,predict.lm(lm1,list(x=acc_us)), col="blue")
```



- Japanese cars:

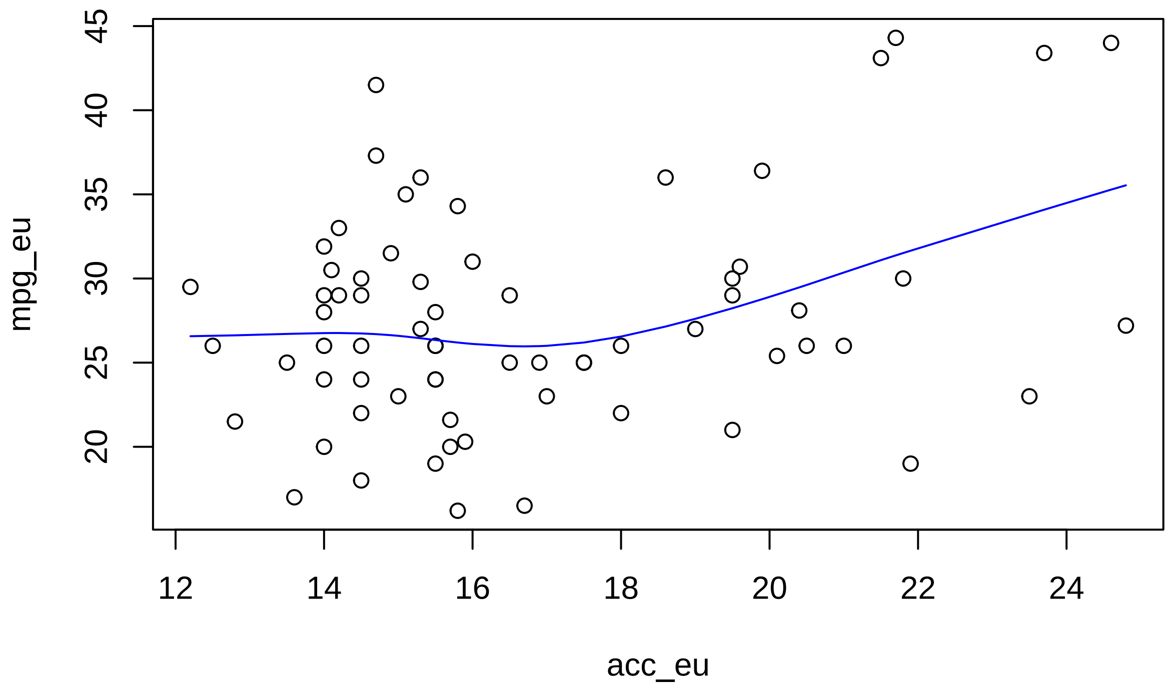
```
plot(acc_jp, mpg_jp)
lm1 <- lm(mpg_jp ~ ns(acc_jp, df=4))
lines(acc_jp,predict.lm(lm1,list(x=acc_jp)), col="blue")
```



Smoothing spline

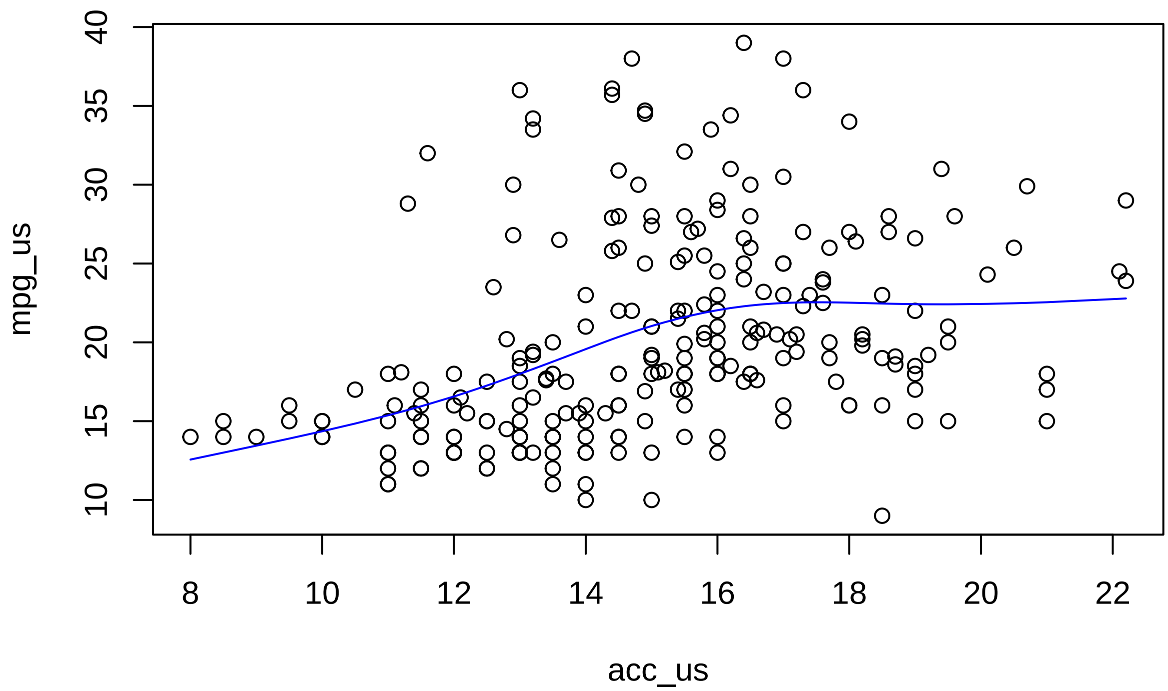
- European cars:

```
plot(mpg_eu ~ acc_eu)
spline_eu <- smooth.spline(acc_eu, mpg_eu, df=4)

lines(spline_eu, col="blue")
```



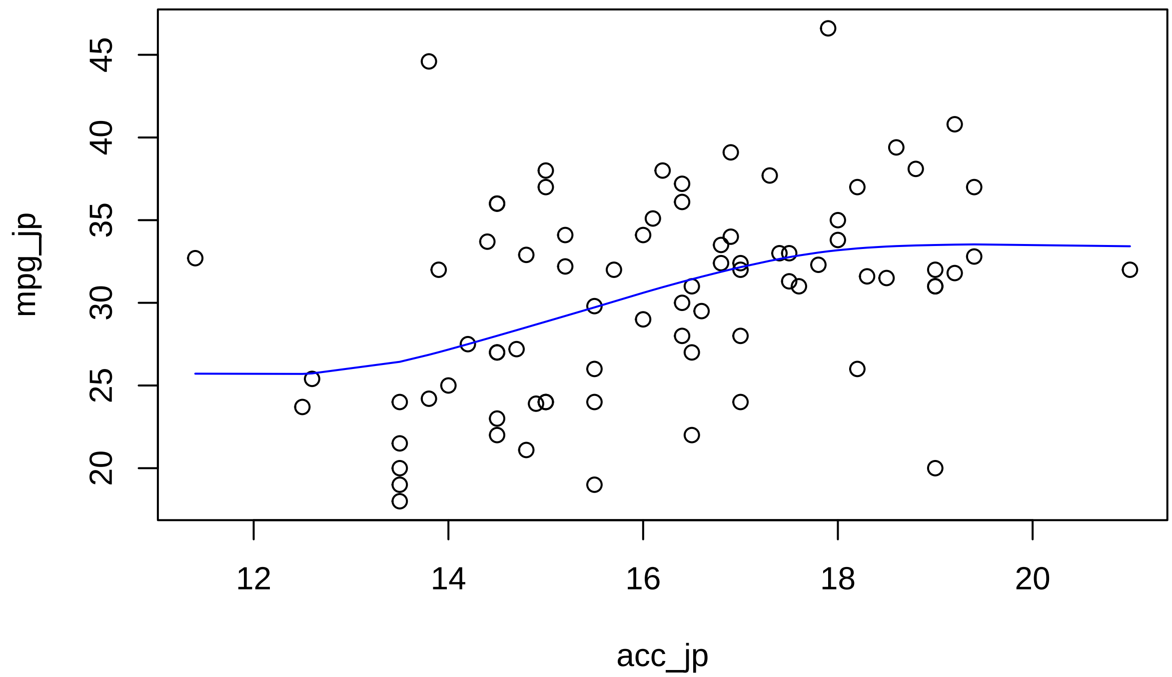
- United states cars:

```
plot(mpg_us ~ acc_us)
spline_us <- smooth.spline(acc_us, mpg_us, df=4)

lines(spline_us, col="blue")
```



- Japanese cars:

```
plot(mpg_jp ~ acc_jp)
spline_us <- smooth.spline(acc_jp, mpg_jp, df=4)

lines(spline_us, col="blue")
```



We can see the different types of splines. In general they are following the same cures though the data with all using degrees of freedom = 4.

Regreesion on the whole data with splines

```
df1 <- df[ , -which(names(df) %in% c("name"))]

str(df1)
```

```
## 'data.frame':    392 obs. of  8 variables:
##  $ mpg         : num  14 14 15 14 15 16 15 14 15 14 ...
##  $ cylinders   : num  8 8 8 8 8 8 8 8 8 8 ...
##  $ displacement: num  340 440 390 454 400 400 429 455 383 455 ...
##  $ horsepower  : num  160 215 190 220 150 230 198 225 170 225 ...
##  $ weight      : num  3609 4312 3850 4354 3761 ...
##  $ acceleration: num  8 8.5 8.5 9 9.5 9.5 10 10 10 10 ...
##  $ year        : num  70 70 70 70 70 73 70 70 70 70 ...
##  $ origin      : num  1 1 1 1 1 1 1 1 1 1 ...
```

```
set.seed(16)

## 2/3 of the sample size
smp_size <- floor(round(nrow(df1)*2/3))
```

```
train_ind <- sample(seq_len(nrow(df1)), size = smp_size)
smp_size
```

```
## [1] 261
```

```
train <- df1[train_ind, ]
test <- df1[-train_ind, ]

# Setting the y to be "Apps"
y_train = train[ , which(names(train) %in% c("mpg"))]
y_test = test[ , which(names(test) %in% c("mpg"))]

# Removing the predictive variable from the training and testing sets.
x_train = train[ , -which(names(train) %in% c("mpg"))]
x_test = test[ , -which(names(test) %in% c("mpg"))]
```

```
str(y_train)
```

```
##  num [1:261] 33.5 25.8 17.5 22 20.6 18 33.5 27 13 31.5 ...
```

```
str(y_test)
```

```
##  num [1:131] 15 14 14 17 13 12 13 11 32.7 14 ...
```

```
str(x_train)
```

```
## 'data.frame':    261 obs. of  7 variables:
##  $ cylinders   : num  4 4 6 6 6 6 4 4 8 4 ...
##  $ displacement: num  98 156 258 225 225 225 85 112 350 98 ...
##  $ horsepower  : num  83 92 95 100 110 105 70 88 145 68 ...
##  $ weight      : num  2075 2620 3193 3233 3360 ...
##  $ acceleration: num  15.9 14.4 17.8 15.4 16.6 16.5 16.8 18.6 13 18.5 ...
##  $ year        : num  77 81 76 76 79 74 77 82 73 77 ...
##  $ origin      : num  1 1 1 1 1 1 3 1 1 3 ...
```

```
str(x_test)
```

```
## 'data.frame':    131 obs. of  7 variables:
##  $ cylinders   : num  8 8 8 8 8 8 8 8 6 8 ...
##  $ displacement: num  390 454 455 302 440 455 360 350 168 400 ...
##  $ horsepower  : num  190 220 225 140 215 225 175 180 132 175 ...
##  $ weight      : num  3850 4354 3086 3449 4735 ...
##  $ acceleration: num  8.5 9 10 10.5 11 11 11 11 11.4 11.5 ...
##  $ year        : num  70 70 70 70 73 73 73 73 80 71 ...
##  $ origin      : num  1 1 1 1 1 1 1 1 3 1 ...
```

```
# Create the linear model with natural cubic splines
model1 <- lm(train$mpg ~ ns(horsepower, df = 4) + ns(displacement, df = 4) + ns(weight, df = 4) + ns(ac

# Summarize the linear model
summary(model1)
```

```
##
## Call:
## lm(formula = train$mpg ~ ns(horsepower, df = 4) + ns(displacement,
##     df = 4) + ns(weight, df = 4) + ns(acceleration, df = 4) +
##     year + cylinders + origin, data = train)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.3208 -1.6088  0.1443  1.4202  8.3130
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)               -20.21801    5.07438  -3.984 8.97e-05 ***
## ns(horsepower, df = 4)1    -6.38007    1.94102  -3.287 0.001164 **
## ns(horsepower, df = 4)2   -10.54480    2.58567  -4.078 6.17e-05 ***
## ns(horsepower, df = 4)3   -15.08432    4.34554  -3.471 0.000614 ***
## ns(horsepower, df = 4)4    -9.08901    3.05745  -2.973 0.003251 **
## ns(displacement, df = 4)1  -3.42039    2.17303  -1.574 0.116796
## ns(displacement, df = 4)2  -6.22686    2.95816  -2.105 0.036329 *
## ns(displacement, df = 4)3  -4.94774    4.19365  -1.180 0.239237
## ns(displacement, df = 4)4  -3.85467    3.65490  -1.055 0.292639
## ns(weight, df = 4)1        -6.06396    2.16338  -2.803 0.005475 **
## ns(weight, df = 4)2        -7.75344    2.52441  -3.071 0.002375 **
## ns(weight, df = 4)3       -10.87782    4.32894  -2.513 0.012631 *
## ns(weight, df = 4)4        -8.78335    2.83696  -3.096 0.002193 **
## ns(acceleration, df = 4)1  -3.17206    2.29715  -1.381 0.168599
## ns(acceleration, df = 4)2  -4.31654    1.69888  -2.541 0.011688 *
## ns(acceleration, df = 4)3  -5.21680    4.73366  -1.102 0.271532
## ns(acceleration, df = 4)4  -0.72205    2.38957  -0.302 0.762785
## year                        0.74107    0.05241  14.139  < 2e-16 ***
## cylinders                   0.84874    0.49382   1.719 0.086947 .
## origin                      0.19921    0.31289   0.637 0.524943
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.728 on 241 degrees of freedom
## Multiple R-squared:  0.8819, Adjusted R-squared:  0.8725
## F-statistic: 94.67 on 19 and 241 DF,  p-value: < 2.2e-16
```

We have two different types of attributes fitted in this model: 1) splines with degrees of freedom = 4, so in the summary all spline attributes exist 4 times. 2) second group of attributes are th categorical ones. We just passed them in the model as we do in other linear models.

We can see as well how significant each one is for the model (acceleration, weight, horsepower and year)

```r
y_pred <- predict(model1, x_test)
RMSE <- sqrt(mean((y_test - y_pred)^2))
RMSE
```

```
## [1] 3.17864
```

For RMSE score we have 2,87. Lets now try the stepwise model.

Stepwise variable selection

```
fit2 <- step(lm(train$mpg ~ ns(horsepower, df = 4) + ns(displacement, df = 4) + ns(weight, df = 4) + ns
```

```
## Start:  AIC=543.04
## train$mpg ~ ns(horsepower, df = 4) + ns(displacement, df = 4) +
##     ns(weight, df = 4) + ns(acceleration, df = 4) + year + cylinders +
##     origin
##
##                          Df Sum of Sq    RSS    AIC
## - origin                  1      3.02 1796.4 541.47
## - ns(displacement, df = 4) 4     47.49 1840.9 541.86
## <none>                               1793.4 543.04
## - cylinders               1     21.98 1815.4 544.22
## - ns(acceleration, df = 4) 4     71.42 1864.8 545.23
## - ns(weight, df = 4)       4    111.19 1904.6 550.74
## - ns(horsepower, df = 4)   4    157.32 1950.7 556.98
## - year                    1   1487.53 3280.9 698.68
##
## Step:  AIC=541.47
## train$mpg ~ ns(horsepower, df = 4) + ns(displacement, df = 4) +
##     ns(weight, df = 4) + ns(acceleration, df = 4) + year + cylinders
##
##                          Df Sum of Sq    RSS    AIC
## <none>                               1796.4 541.47
## + origin                  1      3.02 1793.4 543.04
## - cylinders               1     25.19 1821.6 543.11
## - ns(displacement, df = 4) 4     70.90 1867.3 543.58
## - ns(acceleration, df = 4) 4     71.79 1868.2 543.70
## - ns(weight, df = 4)       4    108.69 1905.1 548.81
## - ns(horsepower, df = 4)   4    154.50 1950.9 555.01
## - year                    1   1484.62 3281.0 696.69
```

```
summary(fit2)
```

```
##
## Call:
## lm(formula = train$mpg ~ ns(horsepower, df = 4) + ns(displacement,
##     df = 4) + ns(weight, df = 4) + ns(acceleration, df = 4) +
##     year + cylinders, data = train)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -7.3449 -1.6081  0.1861  1.4331  8.4453
##
## Coefficients:
##                            Estimate Std. Error t value Pr(>|t|)
## (Intercept)               -19.74931    5.01452  -3.938 0.000107 ***
## ns(horsepower, df = 4)1    -6.27836    1.93206  -3.250 0.001320 **
## ns(horsepower, df = 4)2   -10.47571    2.58021  -4.060 6.63e-05 ***
## ns(horsepower, df = 4)3   -15.01083    4.33866  -3.460 0.000639 ***
## ns(horsepower, df = 4)4    -8.97944    3.04885  -2.945 0.003542 **
```

```
## ns(displacement, df = 4)1  -4.00800    1.96487  -2.040 0.042454 *
## ns(displacement, df = 4)2  -6.93165    2.73985  -2.530 0.012044 *
## ns(displacement, df = 4)3  -5.87030    3.93052  -1.494 0.136604
## ns(displacement, df = 4)4  -4.49638    3.50886  -1.281 0.201266
## ns(weight, df = 4)1        -6.01149    2.15916  -2.784 0.005790 **
## ns(weight, df = 4)2        -7.63595    2.51456  -3.037 0.002654 **
## ns(weight, df = 4)3       -10.87435    4.32361  -2.515 0.012549 *
## ns(weight, df = 4)4        -8.72778    2.83213  -3.082 0.002296 **
## ns(acceleration, df = 4)1  -3.11202    2.29239  -1.358 0.175873
## ns(acceleration, df = 4)2  -4.31640    1.69679  -2.544 0.011586 *
## ns(acceleration, df = 4)3  -5.16044    4.72701  -1.092 0.276054
## ns(acceleration, df = 4)4  -0.68882    2.38606  -0.289 0.773071
## year                        0.73985    0.05232  14.142  < 2e-16 ***
## cylinders                   0.89759    0.48722   1.842 0.066659 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.725 on 242 degrees of freedom
## Multiple R-squared:  0.8817, Adjusted R-squared:  0.8729
## F-statistic: 100.2 on 18 and 242 DF,  p-value: < 2.2e-16
```

The final model excludes of course cylinders and displacement but keeps the origin attribute.

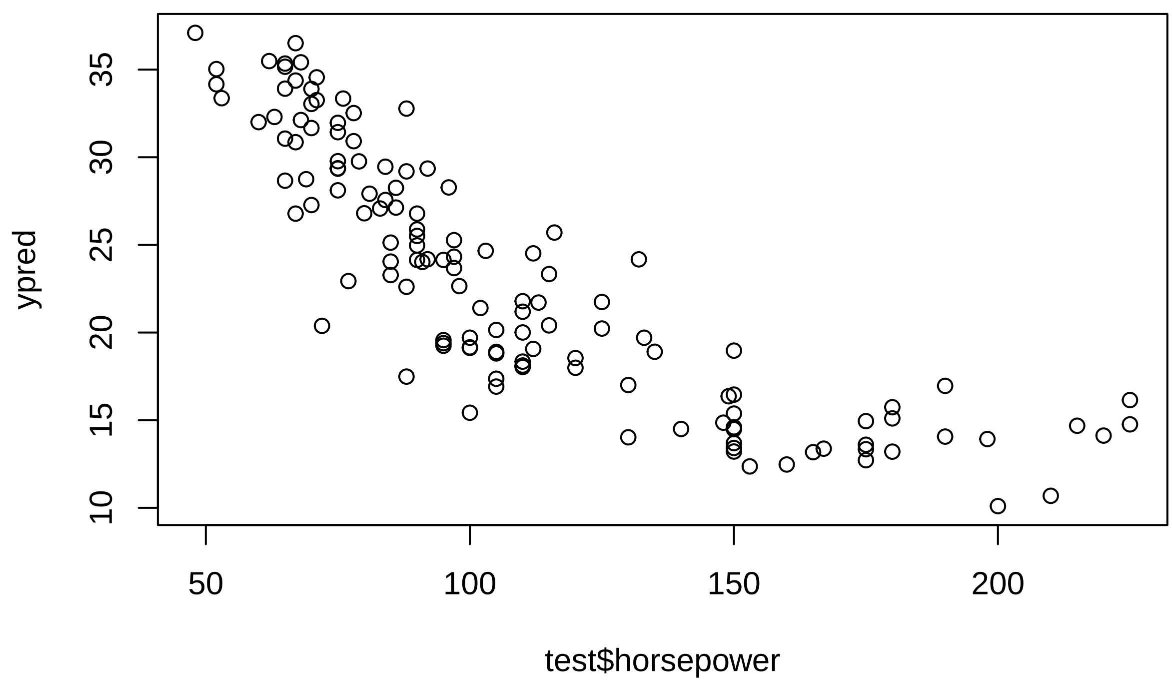
Calculate the RMSE on the test set

```
ypred <- predict(fit2, x_test)
RMSE2 <- sqrt(mean((y_test - ypred)^2))
RMSE2
```

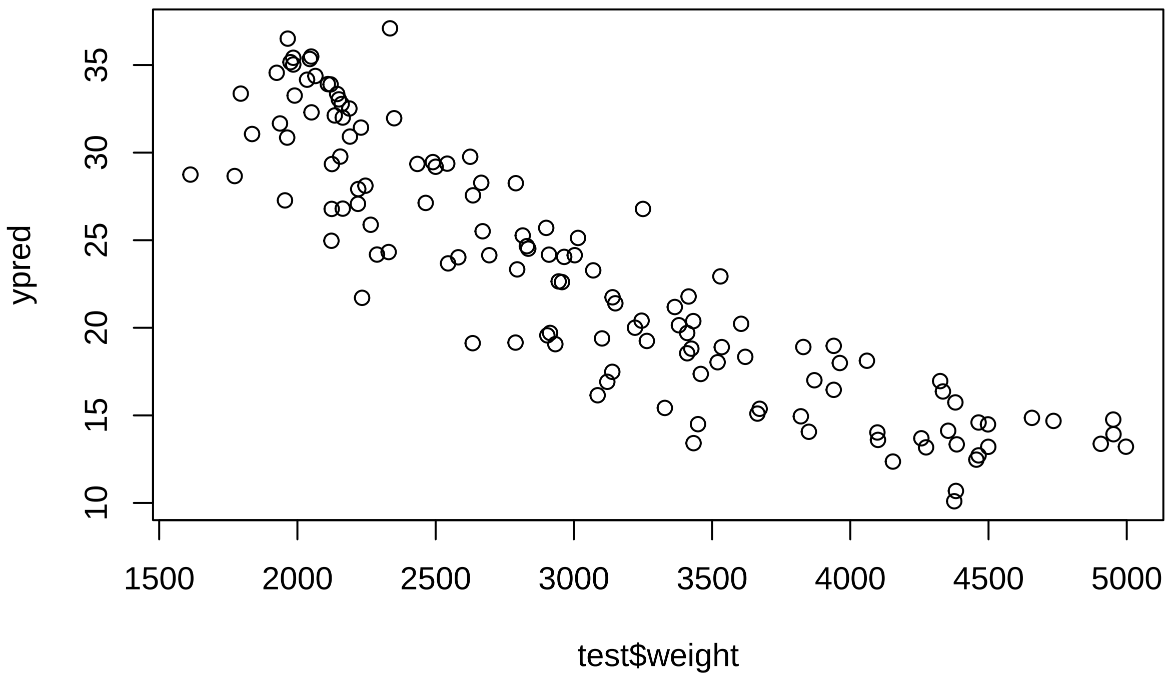
```
## [1] 3.209117
```

We have little bit more error bit with 2 attributes less. Lets plot the variables now.

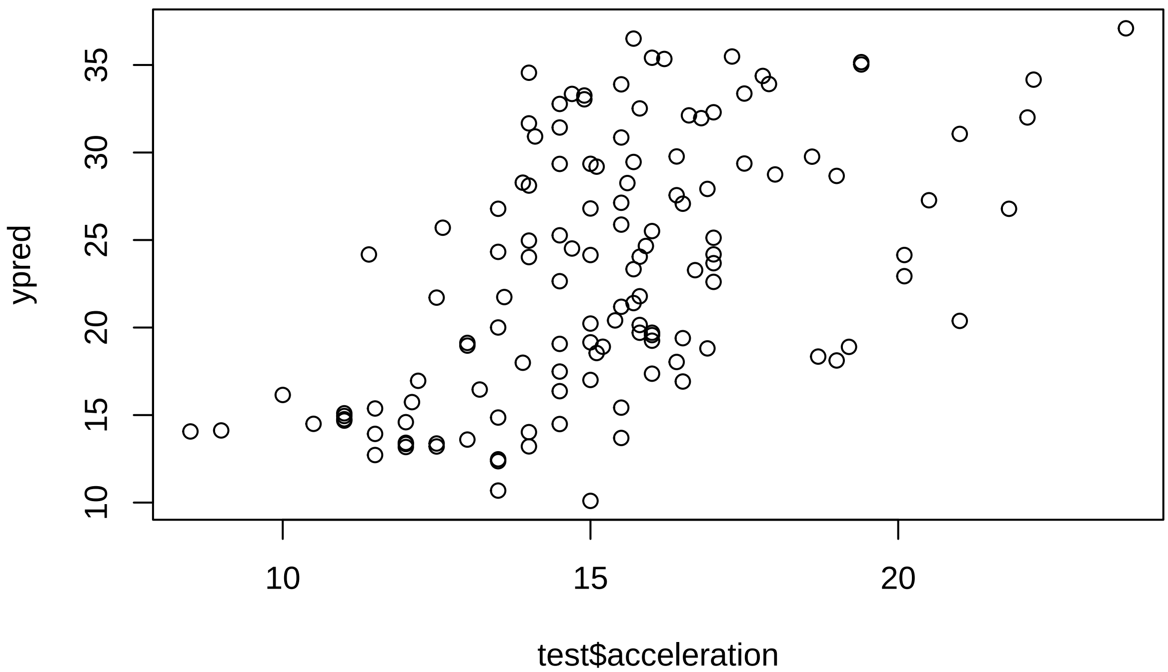
```
plot(test$horsepower, ypred)
```



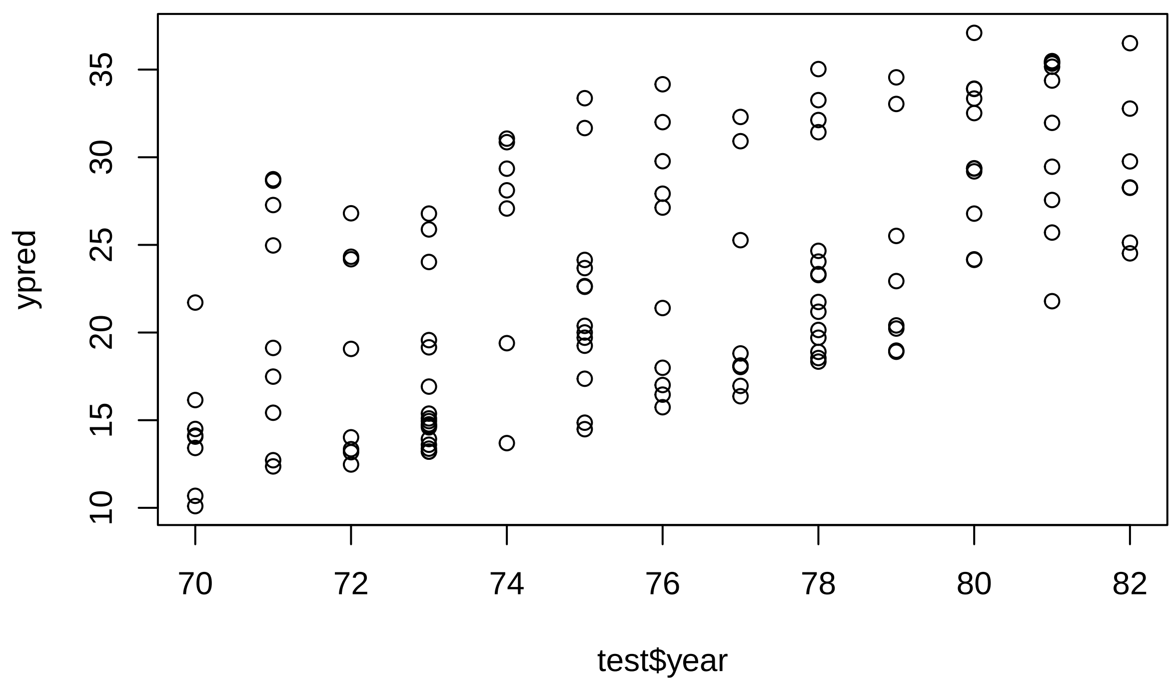

```
plot(test$weight, ypred)
```



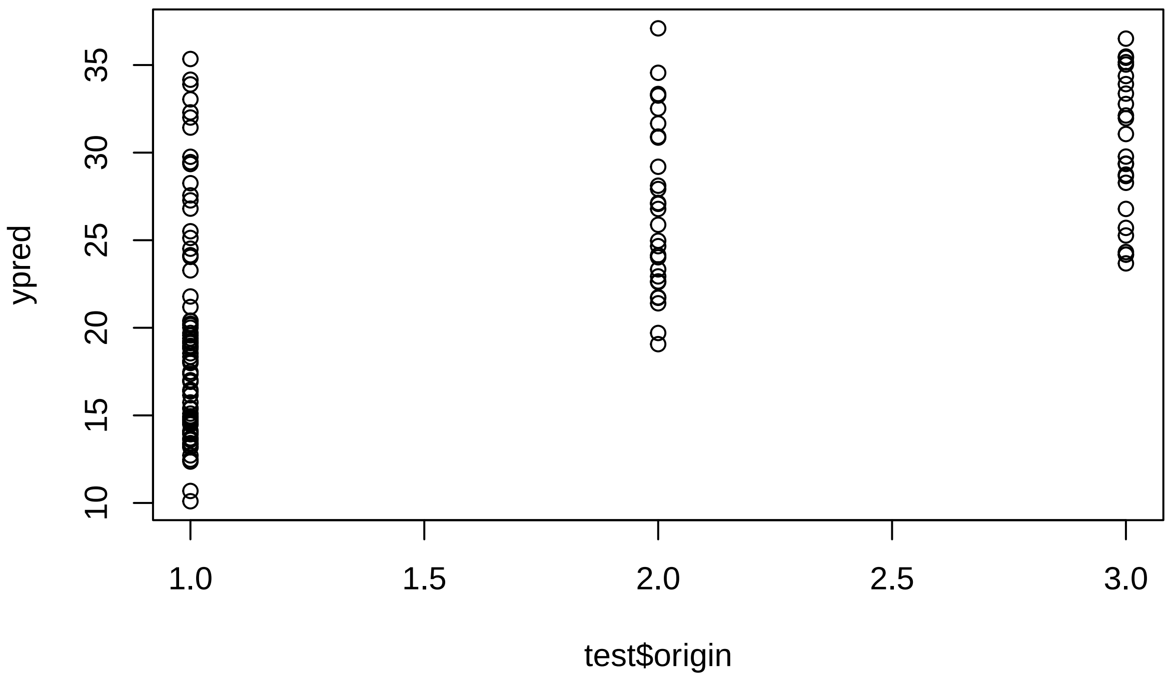

```
plot(test$acceleration, ypred)
```




```
plot(test$year, ypred)
```




```
plot(test$origin, ypred)
```


35
30
25
20
15
10
ypred
1.0
1.5
2.0
2.5
3.0
test$origin