Multiclass logistic regression

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For a similar analysis, look at this tutorial from UCLA. For more about `glmnet`, consult this tutorial by Trevor Hastie.

First, we import the data.

```r
data<-read.csv("hsbdemo.csv")
#View(data)
data
```

```
##   X  id female    ses schtyp     prog read write math science socst
## 1 1  45 female    low public vocation   34    35   41      29    26
## 2 2 108   male middle public  general   34    33   41      36    36
## 3 3  15   male   high public vocation   39    39   44      26    42
## 4 4  67   male    low public vocation   37    37   42      33    32
## 5 5 153   male middle public vocation   39    31   40      39    51
## 6 6  51 female   high public  general   42    36   42      31    39
## 7 7 164   male middle public vocation   31    36   46      39    46
##          honors awards cid
## 1 not enrolled      0   1
## 2 not enrolled      0   1
## 3 not enrolled      0   1
## 4 not enrolled      0   1
## 5 not enrolled      0   1
## 6 not enrolled      0   1
## 7 not enrolled      0   1
##  [ reached 'max' / getOption("max.print") -- omitted 193 rows ]
```

The data set contains variables on 200 students. We will focus on a small subset of predictors. The predictor variables will be socio-economic status `ses` (a three-level categorical variable) and writing score `write` (a quantitative variable). The outcome variable is program type `prog` (a three-level categorical variable). Since I am interested in just this subset, I will create a smaller data frame to analyze.

```r
df=data.frame(data$ses, data$write, data$prog)
colnames(df)<-c("ses", "write", "prog")
attach(df)
```

Some exploratory data analysis is called for. The first idea is, probably to try the `plot` command.

```r
plot(df,
     pch=20, col="lightblue")
```
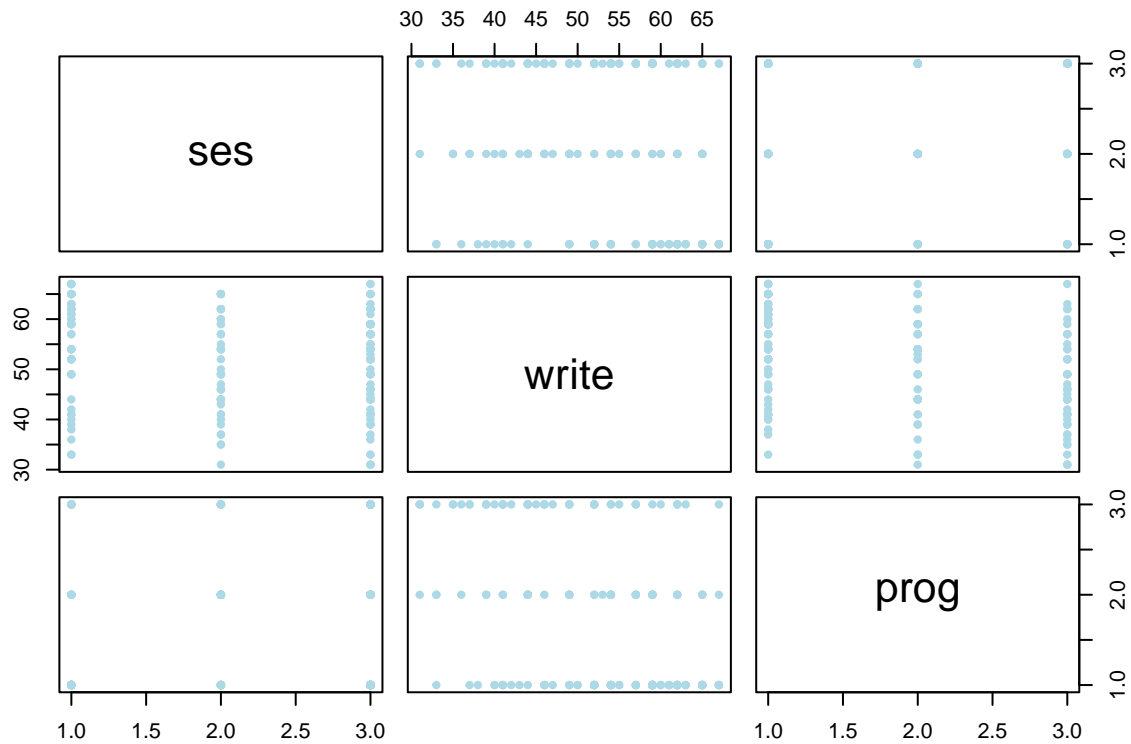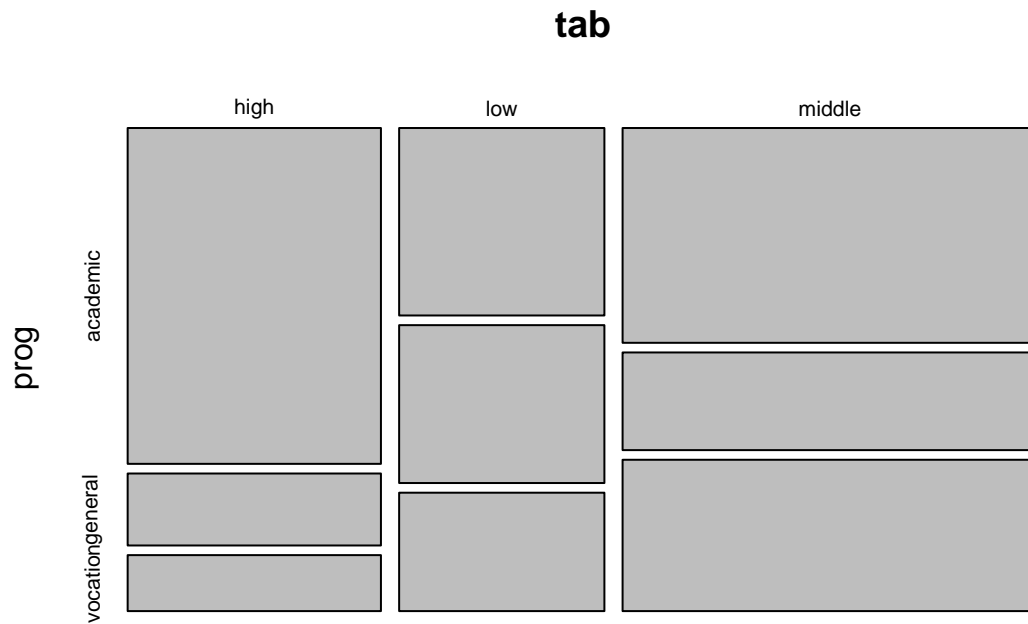
As we can see, this is not too useful. To look at the *association* between `ses` and `prog`, a two-way table might do the trick.

```
tab=table(ses, prog)
tab
```

```
##          prog
## ses       academic general vocation
##    high         42       9        7
##    low          19      16       12
##    middle       44      20       31
```

```
mosaicplot(tab)
```

tab

Which test might we use to test the independence hypothesis?

```
chi2<-chisq.test(tab)
chi2
```

```
##
##  Pearson's Chi-squared test
##
## data:  tab
## X-squared = 16.604, df = 4, p-value = 0.002307
```

What about the association between the writing score and the program type?

Side-by-side boxplots might give insight.

```
write.ac=write[which(prog=="academic")]
write.gen=write[which(prog=="general")]
write.voc=write[which(prog=="vocation")]

boxplot(write.ac,write.gen, write.voc,
  main = "Writing scores by program type",
  ylab = "Writing scores",
  names = c("Academic", "General", "Vocational"),
  col=c("lightblue", "orange", "lightgreen")
)
```

Writing scores by program type
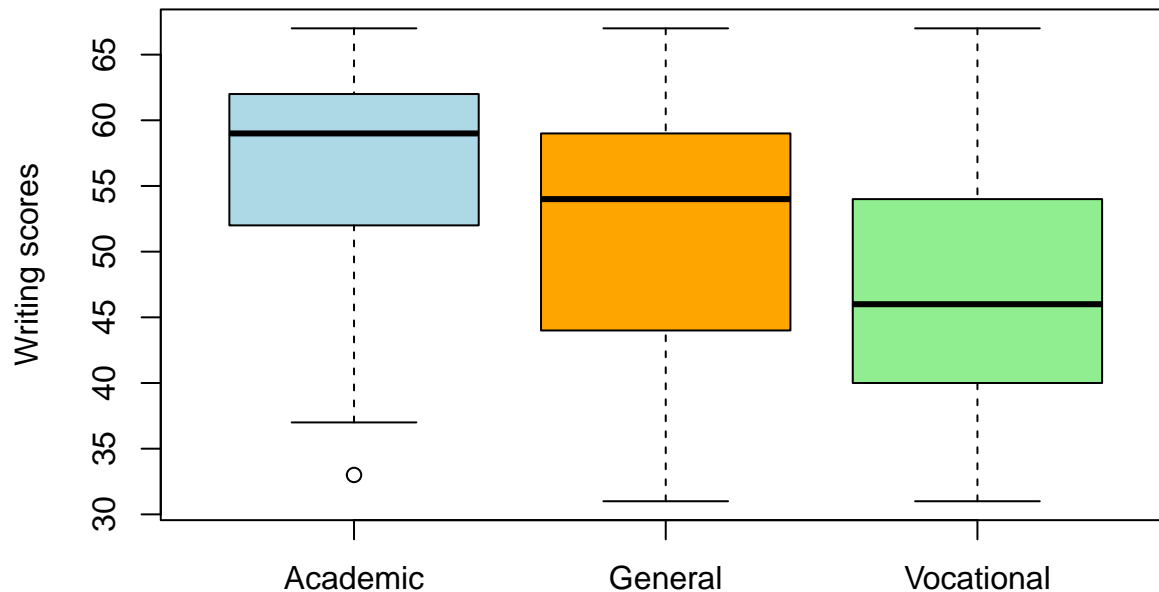
We see that there is an association, but we will learn more about the extent of the effect if we run a multiclass logistic regression.

multinom

Out first option is the `multinom` implementation in the `nnet` package.

```r
#install.packages("nnet")
library(nnet)
```

This implementation requires of us to set a *baseline* level for the response variable.

```r
df$prog<-as.factor(df$prog)
df$prog.base <- relevel(df$prog, ref = "academic")
```

Now, we can run the `multinom` function.

```r
mn.fit<-multinom(prog.base ~ ses + write, data=df)
```

```
## # weights:  15 (8 variable)
## initial  value 219.722458
## iter  10 value 179.983731
## final  value 179.981726
## converged
```

Here is what the object `mn.fit` looks like:

```r
summary(mn.fit)
```

```
## Call:
## multinom(formula = prog.base ~ ses + write, data = df)
##
## Coefficients:
##          (Intercept)    seslow sesmiddle       write
## general     1.689478 1.1628411 0.6295638 -0.05793086
## vocation    4.235574 0.9827182 1.2740985 -0.11360389
```

```
##
## Std. Errors:
##           (Intercept)    seslow sesmiddle      write
## general     1.226939 0.5142211 0.4650289 0.02141101
## vocation    1.204690 0.5955688 0.5111119 0.02222000
##
## Residual Deviance: 359.9635
## AIC: 375.9635
```

Importantly, the coefficients above are **different** from the coefficients one sees in our textbook. However, let us look at the fitted probabilities for our data set.

```
fitted.ps <- fitted(mn.fit)
fitted.ps
```

```
##      academic    general    vocation
## 1   0.1482721 0.33825094 0.51347695
## 2   0.1201988 0.18063349 0.69916776
## 3   0.4186768 0.23681368 0.34450947
## 4   0.1726839 0.35084330 0.47647284
## 5   0.1001206 0.16894278 0.73093666
## 6   0.3533583 0.23780466 0.40883700
## 7   0.1562526 0.19735515 0.64639223
## 8   0.1001206 0.16894278 0.73093666
## 9   0.2331247 0.22040133 0.54647393
## 10  0.1699365 0.20255764 0.62750590
## 11  0.2777676 0.37620933 0.34602312
## 12  0.2917517 0.23361220 0.47463615
## 13  0.1071652 0.30822610 0.58460873
## 14  0.2888732 0.22953872 0.48158807
## 15  0.1482721 0.33825094 0.51347695
## 16  0.2777676 0.37620933 0.34602312
## 17  0.3126201 0.37709158 0.31028831
## 18  0.3293850 0.23309576 0.43751925
## 19  0.3293850 0.23309576 0.43751925
## 20  0.6324633 0.20043456 0.16710218
## 21  0.1998541 0.21215684 0.58798906
## 22  0.2888732 0.22953872 0.48158807
## 23  0.3306561 0.37639804 0.29294591
## 24  0.2777676 0.37620933 0.34602312
## 25  0.1726839 0.35084330 0.47647284
## 26  0.3966353 0.23772687 0.36563784
## 27  0.3676891 0.37276358 0.25954735
## 28  0.2888732 0.22953872 0.48158807
## 29  0.2291956 0.36934430 0.40146013
## 30  0.3865745 0.36985112 0.24357436
## 31  0.2888732 0.22953872 0.48158807
## 32  0.1996861 0.36131931 0.43899458
## 33  0.2141360 0.36565697 0.42020707
##  [ reached 'max' / getOption("max.print") -- omitted 167 rows ]
```

Also importantly, we do not have $p-$values reported above. We can figure them out easily, though.

```
z.scores<- summary(mn.fit)$coefficients/summary(mn.fit)$standard.errors
p.val=2*(1-pnorm(abs(z.scores)))
p.val
```

```
##          (Intercept)      seslow sesmiddle           write
## general  0.1685163893 0.02373673 0.1757949 0.0068169138868
## vocation 0.0004382601 0.09893276 0.0126741 0.0000003176088
```

How well did we do on the training set?

```
pred.mn.tr=predict(mn.fit, newdata = df, "class")
#pred.mn.tr
ind.tr=(pred.mn.tr==prog)
mean(ind.tr)
```

```
## [1] 0.61
```

How would we predict for a test case? First, we need to define what the inputs for the test case would be.

```
new.data <- data.frame(ses = c("low", "middle", "high"), write = c(quantile(df$write, 0.25), median(df$w
```

Now, we can use the `predict` command to see what the predicted probabilities would be.

```
pred.mn=predict(mn.fit, newdata = new.data, "probs")
pred.mn
```

```
##      academic    general    vocation
## 25% 0.3081702 0.3771467 0.31468315
##     0.5049235 0.2247935 0.27028295
## 75% 0.8043171 0.1347768 0.06090615
```

glmnet

Here, we need to install and load a package create by Hastie et al.

```
#install.packages("glmnet")
library(glmnet)
```

```
## Loading required package: Matrix
```

```
## Loaded glmnet 4.1-10
```

We notice that we need to transform our categorical predictor using dummy variables. For that, the following library is useful:

```
library(caret)
```

```
## Loading required package: ggplot2
```

```
## Loading required package: lattice
```

First, I will put all of my predictors into a separate data frame.

```
temp.x=data.frame(data$ses, data$write)
```

Now, I will use the command `dummyVars` to create dummy variables for my one categorical predictor `ses` in my array of predictors.

```
dummy.x <- dummyVars(" ~ .", data = temp.x)
x <- as.matrix(predict(dummy.x, newdata = temp.x))
print(x)
```

```
##    data.seshigh data.seslow data.sesmiddle data.write
## 1             0           1              0         35
## 2             0           0              1         33
## 3             1           0              0         39
```

```
## 4                   0            1            0           37
## 5                   0            0            1           31
## 6                   1            0            0           36
## 7                   0            0            1           36
## 8                   0            0            1           31
## 9                   0            0            1           41
## 10                  0            0            1           37
## 11                  0            1            0           44
## 12                  1            0            0           33
## 13                  0            1            0           31
## 14                  0            0            1           44
## 15                  0            1            0           35
## 16                  0            1            0           44
## 17                  0            1            0           46
## 18                  0            0            1           46
## 19                  0            0            1           46
## 20                  1            0            0           49
## 21                  0            0            1           39
## 22                  0            0            1           44
## 23                  0            1            0           47
## 24                  0            1            0           44
## 25                  0            1            0           37
##  [ reached 'max' / getOption("max.print") -- omitted 175 rows ]
```

Now, we would like to fit the model using `glmnet`.

```
y <- df$prog
#y
glm.fit <- glmnet(x, y, family = "multinomial")
#summary(glm.fit)
#glm.fit
predict(glm.fit, newx=x, s=0, type="response")
```

```
## , , s=0
##
##       academic     general    vocation
## 1    0.1526166 0.33690080 0.51048259
## 2    0.1240333 0.18489797 0.69106876
## 3    0.4172688 0.23461004 0.34812117
## 4    0.1771834 0.34881146 0.47400509
## 5    0.1037572 0.17343832 0.72280443
## 6    0.3528570 0.23557453 0.41156851
## 7    0.1602391 0.20117013 0.63859078
## 8    0.1037572 0.17343832 0.72280443
## 9    0.2368129 0.22328970 0.53989743
## 10   0.1739242 0.20620006 0.61987571
## 11   0.2822784 0.37220402 0.34551754
## 12   0.2921047 0.23156195 0.47633332
## 13   0.1110538 0.30824709 0.58069910
## 14   0.2919886 0.23186238 0.47614904
## 15   0.1526166 0.33690080 0.51048259
## 16   0.2822784 0.37220402 0.34551754
## 17   0.3169693 0.37272452 0.31030614
## 18   0.3319611 0.23508177 0.43295716
## 19   0.3319611 0.23508177 0.43295716
```

```
## 20   0.6288569 0.19944323 0.17169987
## 21   0.2037564 0.21543051 0.58081312
## 22   0.2919886 0.23186238 0.47614904
## 23   0.3348986 0.37189274 0.29320866
## 24   0.2822784 0.37220402 0.34551754
## 25   0.1771834 0.34881146 0.47400509
## 26   0.3955289 0.23549149 0.36897962
## 27   0.3716716 0.36807063 0.26025772
## 28   0.2919886 0.23186238 0.47614904
## 29   0.2338110 0.36607265 0.40011633
## 30   0.3904065 0.36510890 0.24448463
## 31   0.2919886 0.23186238 0.47614904
## 32   0.2042785 0.35863911 0.43708236
## 33   0.2187490 0.36267251 0.41857853
##
##  [ reached 'max' / getOption("max.print") -- omitted 167 rows ]
```

What if I try to find, by cross-validation, an optimal tuning parameter?

```r
cv.fit <- cv.glmnet(x, y, family = "multinomial")
plot(cv.fit)
```
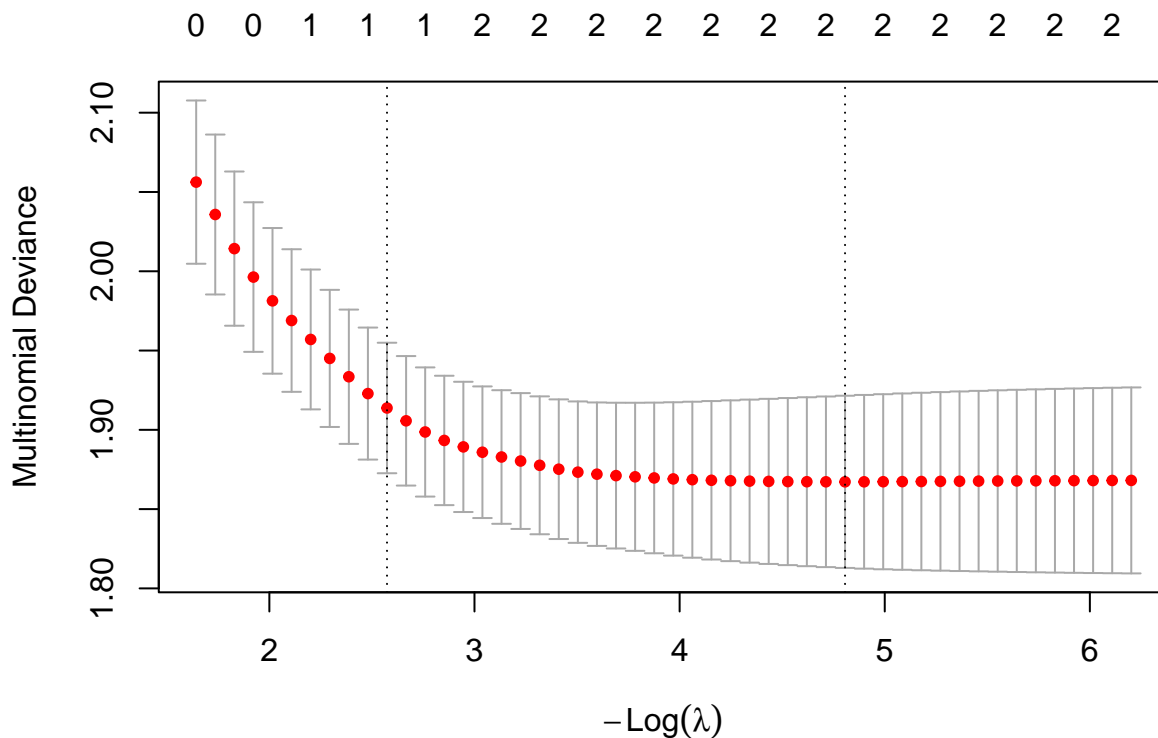

Now, we can try to predict at the optimal λ:

```r
predict(cv.fit, newx = x, s = "lambda.min", type = "class")
```

```
##          lambda.min
##   [1,] "vocation"
##   [2,] "vocation"
##   [3,] "academic"
##   [4,] "vocation"
##   [5,] "vocation"
```

```
##    [6,] "vocation"
##    [7,] "vocation"
##    [8,] "vocation"
##    [9,] "vocation"
##   [10,] "vocation"
##   [11,] "general"
##   [12,] "vocation"
##   [13,] "vocation"
##   [14,] "vocation"
##   [15,] "vocation"
##   [16,] "general"
##   [17,] "general"
##   [18,] "vocation"
##   [19,] "vocation"
##   [20,] "academic"
##   [21,] "vocation"
##   [22,] "vocation"
##   [23,] "general"
##   [24,] "general"
##   [25,] "vocation"
##   [26,] "academic"
##   [27,] "academic"
##   [28,] "vocation"
##   [29,] "vocation"
##   [30,] "academic"
##   [31,] "vocation"
##   [32,] "vocation"
##   [33,] "vocation"
##   [34,] "general"
##   [35,] "vocation"
##   [36,] "vocation"
##   [37,] "vocation"
##   [38,] "academic"
##   [39,] "vocation"
##   [40,] "vocation"
##   [41,] "vocation"
##   [42,] "academic"
##   [43,] "academic"
##   [44,] "academic"
##   [45,] "general"
##   [46,] "academic"
##   [47,] "vocation"
##   [48,] "academic"
##   [49,] "vocation"
##   [50,] "academic"
##   [51,] "vocation"
##   [52,] "vocation"
##   [53,] "general"
##   [54,] "academic"
##   [55,] "academic"
##   [56,] "academic"
##   [57,] "academic"
##   [58,] "academic"
##   [59,] "academic"
```

```
##   [60,] "vocation"
##   [61,] "academic"
##   [62,] "vocation"
##   [63,] "academic"
##   [64,] "academic"
##   [65,] "academic"
##   [66,] "vocation"
##   [67,] "academic"
##   [68,] "academic"
##   [69,] "academic"
##   [70,] "academic"
##   [71,] "academic"
##   [72,] "academic"
##   [73,] "academic"
##   [74,] "academic"
##   [75,] "academic"
##   [76,] "academic"
##   [77,] "academic"
##   [78,] "academic"
##   [79,] "vocation"
##   [80,] "vocation"
##   [81,] "academic"
##   [82,] "academic"
##   [83,] "academic"
##   [84,] "general"
##   [85,] "academic"
##   [86,] "general"
##   [87,] "academic"
##   [88,] "vocation"
##   [89,] "academic"
##   [90,] "vocation"
##   [91,] "academic"
##   [92,] "academic"
##   [93,] "academic"
##   [94,] "academic"
##   [95,] "academic"
##   [96,] "academic"
##   [97,] "academic"
##   [98,] "academic"
##   [99,] "vocation"
## [100,] "vocation"
##  [ reached 'max' / getOption("max.print") -- omitted 100 rows ]
```

We might want to see how well we did on the training data.

```
preds=predict(cv.fit, newx = x, s = "lambda.min", type = "class")
#preds
ind=(preds==y)
mean(ind)
```

```
## [1] 0.595
```