Predictive Modeling
Lesson 3
Logistical Regression and Neural Networks

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Introduction

The RStudio project files and accompanying artifacts, including the tex file that created this PDF, are publicly available on GitHub
`https://github.com/zollie/PASS-PredictiveModeling-LogisticalRegression`

Data Setup

I took the Excel spreadsheet and saved it as a CSV for easy import into R

```
> gc <- read.csv("~/R/PASS/PredictiveModeling/LogisticRegression/GermanCredit.csv")
> head(gc)
```

```
  OBS. CHK_ACCT DURATION HISTORY NEW_CAR USED_CAR FURNITURE RADIO.TV EDUCATION
1    1        0        6       4       0        0         0        1         0
2    2        1       48       2       0        0         0        1         0
3    3        3       12       4       0        0         0        0         1
4    4        0       42       2       0        0         1        0         0
5    5        0       24       3       1        0         0        0         0
6    6        3       36       2       0        0         0        0         1
  RETRAINING AMOUNT SAV_ACCT EMPLOYMENT INSTALL_RATE MALE_DIV MALE_SINGLE
1          0   1169        4          4            4        0           1
2          0   5951        0          2            2        0           0
3          0   2096        0          3            2        0           1
4          0   7882        0          3            2        0           1
5          0   4870        0          2            3        0           1
6          0   9055        4          2            2        0           1
  MALE_MAR_or_WID CO.APPLICANT GUARANTOR PRESENT_RESIDENT REAL_ESTATE
1               0            0         0                4           1
2               0            0         0                2           1
3               0            0         0                3           1
```

```
4               0             0         1                4           0
5               0             0         0                4           0
6               0             0         0                4           0
  PROP_UNKN_NONE AGE OTHER_INSTALL RENT OWN_RES NUM_CREDITS JOB NUM_DEPENDENTS
1              0  67             0    0       1           2   2              1
2              0  22             0    0       1           1   2              1
3              0  49             0    0       1           1   1              2
4              0  45             0    0       0           1   2              2
5              1  53             0    0       0           2   2              2
6              1  35             0    0       0           1   1              2
  TELEPHONE FOREIGN RESPONSE
1         1       0        1
2         0       0        0
3         0       0        1
4         0       0        1
5         0       0        0
6         1       0        1
```

The categorical predictors are turned into factors for R

```
> gc$RESPONSE <- factor(gc$RESPONSE)
> gc$JOB <- factor(gc$JOB)
> gc$EMPLOYMENT <- factor(gc$EMPLOYMENT)
> gc$SAV_ACCT <- factor(gc$SAV_ACCT)
> gc$HISTORY <- factor(gc$HISTORY)
> gc$CHK_ACCT <- factor(gc$CHK_ACCT)
```

Partitioning

Next, the data is paritioned into 60% Train and 40% Test sets. I set the RNG seed for reproducibility

```
> n <- nrow(gc)
> a <- sort(sample(1:n, floor(n*.6)))
> gc.train <- gc[a,]
> gc.test <- gc[-a,]
```

Logistical Regression

A Logistical Regression model is fit to the train data.

```
> logit <- glm(RESPONSE ~ CHK_ACCT+DURATION+HISTORY+NEW_CAR+USED_CAR+FURNITURE+RADIO.TV+EDUC
> logit

Call:  glm(formula = RESPONSE ~ CHK_ACCT + DURATION + HISTORY + NEW_CAR +
    USED_CAR + FURNITURE + RADIO.TV + EDUCATION + RETRAINING +
```

```
    AMOUNT + SAV_ACCT + EMPLOYMENT + INSTALL_RATE + MALE_DIV +
    MALE_SINGLE + MALE_MAR_or_WID + CO.APPLICANT + GUARANTOR +
    PRESENT_RESIDENT + REAL_ESTATE + PROP_UNKN_NONE + AGE + OTHER_INSTALL +
    RENT + OWN_RES + NUM_CREDITS + JOB + NUM_DEPENDENTS + TELEPHONE +
    FOREIGN, family = binomial("logit"), data = gc.train)

Coefficients:
     (Intercept)         CHK_ACCT1         CHK_ACCT2         CHK_ACCT3
       0.0130190         0.6274385         1.5478081         1.7756171
        DURATION          HISTORY1          HISTORY2          HISTORY3
      -0.0213973         0.6218902         1.0542574         0.9128612
        HISTORY4           NEW_CAR          USED_CAR         FURNITURE
       1.9196216        -0.2966938         1.5245519         0.7469575
        RADIO.TV         EDUCATION        RETRAINING            AMOUNT
       0.6227738        -0.3288723         0.3219821        -0.0001606
       SAV_ACCT1         SAV_ACCT2         SAV_ACCT3         SAV_ACCT4
       0.1330299         0.3061612         1.2335501         1.0533710
     EMPLOYMENT1       EMPLOYMENT2       EMPLOYMENT3       EMPLOYMENT4
      -0.2979299         0.1749510         0.4841481        -0.2144694
    INSTALL_RATE          MALE_DIV       MALE_SINGLE   MALE_MAR_or_WID
      -0.3948298         0.1672193         0.7121614         0.1611906
    CO.APPLICANT         GUARANTOR  PRESENT_RESIDENT       REAL_ESTATE
      -0.7918356         0.9532831         0.0169459         0.5110658
  PROP_UNKN_NONE               AGE     OTHER_INSTALL              RENT
      -0.1388947         0.0097773        -0.4422190        -0.2464168
         OWN_RES       NUM_CREDITS              JOB1              JOB2
       0.2746791         0.0027873        -0.2988528        -0.2699509
            JOB3    NUM_DEPENDENTS         TELEPHONE           FOREIGN
       0.2313653        -0.4014251         0.4155514         0.3403382

Degrees of Freedom: 599 Total (i.e. Null);  556 Residual
Null Deviance:          724.4
Residual Deviance: 520.1        AIC: 608.1

> summary(logit)

Call:
glm(formula = RESPONSE ~ CHK_ACCT + DURATION + HISTORY + NEW_CAR +
    USED_CAR + FURNITURE + RADIO.TV + EDUCATION + RETRAINING +
    AMOUNT + SAV_ACCT + EMPLOYMENT + INSTALL_RATE + MALE_DIV +
    MALE_SINGLE + MALE_MAR_or_WID + CO.APPLICANT + GUARANTOR +
    PRESENT_RESIDENT + REAL_ESTATE + PROP_UNKN_NONE + AGE + OTHER_INSTALL +
    RENT + OWN_RES + NUM_CREDITS + JOB + NUM_DEPENDENTS + TELEPHONE +
    FOREIGN, family = binomial("logit"), data = gc.train)

Deviance Residuals:
```

```
    Min       1Q   Median       3Q      Max
-2.9686  -0.6543   0.3575   0.6694   2.1016

Coefficients:
                   Estimate Std. Error z value Pr(>|z|)
(Intercept)       1.302e-02  1.605e+00   0.008 0.993529
CHK_ACCT1         6.274e-01  2.846e-01   2.205 0.027471 *
CHK_ACCT2         1.548e+00  5.064e-01   3.057 0.002239 **
CHK_ACCT3         1.776e+00  3.051e-01   5.821 5.86e-09 ***
DURATION         -2.140e-02  1.302e-02  -1.644 0.100179
HISTORY1          6.219e-01  7.124e-01   0.873 0.382692
HISTORY2          1.054e+00  5.711e-01   1.846 0.064890 .
HISTORY3          9.129e-01  6.232e-01   1.465 0.142966
HISTORY4          1.920e+00  5.942e-01   3.231 0.001235 **
NEW_CAR          -2.967e-01  6.039e-01  -0.491 0.623239
USED_CAR          1.525e+00  7.304e-01   2.087 0.036868 *
FURNITURE         7.470e-01  6.284e-01   1.189 0.234582
RADIO.TV          6.228e-01  6.049e-01   1.029 0.303258
EDUCATION        -3.289e-01  7.172e-01  -0.459 0.646553
RETRAINING        3.220e-01  6.680e-01   0.482 0.629820
AMOUNT           -1.606e-04  6.272e-05  -2.560 0.010471 *
SAV_ACCT1         1.330e-01  3.926e-01   0.339 0.734702
SAV_ACCT2         3.062e-01  5.367e-01   0.570 0.568363
SAV_ACCT3         1.234e+00  6.603e-01   1.868 0.061757 .
SAV_ACCT4         1.053e+00  3.452e-01   3.051 0.002278 **
EMPLOYMENT1      -2.979e-01  6.147e-01  -0.485 0.627913
EMPLOYMENT2       1.750e-01  6.060e-01   0.289 0.772825
EMPLOYMENT3       4.841e-01  6.461e-01   0.749 0.453681
EMPLOYMENT4      -2.145e-01  5.992e-01  -0.358 0.720383
INSTALL_RATE     -3.948e-01  1.165e-01  -3.390 0.000699 ***
MALE_DIV          1.672e-01  5.252e-01   0.318 0.750180
MALE_SINGLE       7.122e-01  2.872e-01   2.480 0.013136 *
MALE_MAR_or_WID   1.612e-01  4.036e-01   0.399 0.689600
CO.APPLICANT     -7.918e-01  4.855e-01  -1.631 0.102869
GUARANTOR         9.533e-01  5.439e-01   1.753 0.079671 .
PRESENT_RESIDENT  1.695e-02  1.175e-01   0.144 0.885307
REAL_ESTATE       5.111e-01  2.919e-01   1.751 0.079948 .
PROP_UNKN_NONE   -1.389e-01  5.371e-01  -0.259 0.795927
AGE               9.777e-03  1.242e-02   0.788 0.430972
OTHER_INSTALL    -4.422e-01  2.787e-01  -1.587 0.112531
RENT             -2.464e-01  6.414e-01  -0.384 0.700847
OWN_RES           2.747e-01  6.029e-01   0.456 0.648703
NUM_CREDITS       2.787e-03  2.402e-01   0.012 0.990743
JOB1             -2.989e-01  9.660e-01  -0.309 0.757048
JOB2             -2.700e-01  9.374e-01  -0.288 0.773358
JOB3              2.314e-01  9.346e-01   0.248 0.804472
```

```
NUM_DEPENDENTS   -4.014e-01  3.255e-01  -1.233 0.217500
TELEPHONE         4.156e-01  2.630e-01   1.580 0.114081
FOREIGN           3.403e-01  7.422e-01   0.459 0.646558
---
Signif. codes:  0 âĂŸ***âĂŹ 0.001 âĂŸ**âĂŹ 0.01 âĂŸ*âĂŹ 0.05 âĂŸ.âĂŹ 0.1 âĂŸ âĂŹ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 724.36  on 599  degrees of freedom
Residual deviance: 520.15  on 556  degrees of freedom
AIC: 608.15

Number of Fisher Scoring iterations: 5

> confint(logit)

                        2.5 %        97.5 %
(Intercept)      -3.1088217929  3.205295e+00
CHK_ACCT1         0.0730383976  1.190740e+00
CHK_ACCT2         0.6033382534  2.608454e+00
CHK_ACCT3         1.1893883645  2.388138e+00
DURATION         -0.0471800654  4.028345e-03
HISTORY1         -0.7641375436  2.043542e+00
HISTORY2         -0.0420924161  2.213788e+00
HISTORY3         -0.2860916509  2.170036e+00
HISTORY4          0.7802222009  3.123767e+00
NEW_CAR          -1.5256645097  8.645935e-01
USED_CAR          0.0854573119  2.968877e+00
FURNITURE        -0.5220082124  1.963286e+00
RADIO.TV         -0.6057609977  1.789263e+00
EDUCATION        -1.7666887512  1.062207e+00
RETRAINING       -1.0136186649  1.624869e+00
AMOUNT           -0.0002847035 -3.794786e-05
SAV_ACCT1        -0.6231690751  9.217988e-01
SAV_ACCT2        -0.6920073338  1.440611e+00
SAV_ACCT3         0.0378169851  2.675750e+00
SAV_ACCT4         0.3951067980  1.753439e+00
EMPLOYMENT1      -1.5252554394  8.991256e-01
EMPLOYMENT2      -1.0343351917  1.356605e+00
EMPLOYMENT3      -0.7968523911  1.750967e+00
EMPLOYMENT4      -1.4174238024  9.456194e-01
INSTALL_RATE     -0.6271862178 -1.696799e-01
MALE_DIV         -0.8480863667  1.225398e+00
MALE_SINGLE       0.1522385488  1.280286e+00
MALE_MAR_or_WID  -0.6208394998  9.674190e-01
CO.APPLICANT     -1.7543180324  1.630764e-01
```

```
GUARANTOR        -0.0535686993  2.105975e+00
PRESENT_RESIDENT -0.2136948389  2.477828e-01
REAL_ESTATE      -0.0547834291  1.092135e+00
PROP_UNKN_NONE   -1.1850501887  9.279768e-01
AGE              -0.0142842077  3.450442e-02
OTHER_INSTALL    -0.9872548856  1.079713e-01
RENT             -1.5077823881  1.013876e+00
OWN_RES          -0.9061387196  1.465613e+00
NUM_CREDITS      -0.4682461593  4.782817e-01
JOB1             -2.3045383941  1.533273e+00
JOB2             -2.2278672639  1.499925e+00
JOB3             -1.7166728082  2.005040e+00
NUM_DEPENDENTS   -1.0371197579  2.424741e-01
TELEPHONE        -0.0965757578  9.364935e-01
FOREIGN          -1.0238410353  1.938145e+00
```

> *residuals(logit)*

```
          1           2           4           6           9          10 
 0.24762860 -1.21427984  0.99415371  0.78194692  0.14388602 -1.08584589 
         12          13          14          16          17          18 
-0.41187164  0.54221809 -1.21270868 -1.02217785  0.23278129  1.82708699 
         20          23          24          26          27          28 
 0.50908094  0.75460042  0.31096173  0.41574845  0.93225559  0.34908713 
         29          30          31          32          35          37 
 0.32423566 -0.70947614  0.57133002  1.08781747  0.66048002  0.66894075 
         38          39          40          42          43          44 
-1.66666261  0.35734468  0.56299870  0.59781397  0.83662433  0.60768594 
         45          46          47          48          49          50 
-0.79459969  0.60772598  0.60482268  0.46128567  0.39021223  0.71370251 
         51          53          55          58          59          60 
 0.87859713  0.37976129 -0.73886534  0.82124259  0.94087228 -0.47350270 
         61          64          65          66          67          68 
 0.62933676 -0.50793516  0.82330960  0.61503667  0.70856848  0.68839058 
         69          70          72          75          76          79 
-1.33132911  0.53336746  0.19110584 -1.38032193  0.44059609  0.66861140 
         80          81          85          86          87          90 
 1.13684281 -2.40308121  0.76400942  0.15239383  0.88821966 -1.02879570 
         91          92          93          94          95          96 
 0.22924883  0.38063697 -2.19421182  0.62746997  0.45626522 -0.24070372 
         97          98          99         100         103         105 
 0.31261933  0.91371105  0.63681670  0.46660626  0.41229081  0.22457524 
        106         113         115         117         118         124 
-1.17392065  1.21530388  0.89494465 -1.38006600  0.62009275  0.49042993 
        125         127         130         134         135         136 
-1.54602580  0.93889623 -0.95574227  0.64209963  0.73000774  0.18351204 
```

137	138	139	140	142	146
0.24355414	-2.20380844	0.14719867	0.50381967	1.35381410	1.32126102
147	149	150	151	153	154
0.75978213	0.60113285	0.19335876	0.45733607	0.90018618	0.53986815
159	161	162	163	164	166
0.83838591	0.26214578	0.82640198	0.36600298	1.03184946	0.17685672
168	169	171	172	174	175
0.59573324	0.51680993	-0.34713454	0.37670167	0.31258457	-0.82745183
177	178	179	183	184	186
0.88698489	0.55766824	0.40669257	-1.00862405	0.11787603	0.30490007
187	188	190	192	193	194
-1.54110660	0.41813025	1.07973227	-0.56101852	-1.23060219	0.34898800
196	197	198	199	202	206
-1.93385685	0.18348132	-0.88726734	0.54804285	1.40193167	0.94466340
207	208	209	211	212	213
0.20698744	0.60569371	1.73684946	0.10151912	0.29105270	-0.78096448
215	217	218	219	220	222
0.23798728	1.45719464	0.35578645	1.09216514	0.45547222	1.49035945
223	227	228	229	232	234
0.41512509	-1.40237701	-1.13874246	-2.27426574	0.58053610	0.53543527
235	237	238	239	242	247
0.14686943	-1.55461797	-0.75035435	0.40734304	0.33860355	0.23490793
250	251	254	255	257	259
-1.58167508	0.32897359	0.39706064	0.22581971	0.28806558	0.28420911
260	261	262	265	266	268
0.28504319	0.55213452	1.46876896	0.35655209	-1.35280874	0.85057032
269	271	272	273	276	277
-1.15980608	0.35821882	0.24281990	2.10154673	0.25688979	0.33664300
279	280	281	282	283	285
-2.06892280	0.40864956	0.14320935	0.30748791	0.38954531	1.19125853
286	287	289	291	292	294
1.97048387	1.21042453	0.39404435	0.25087576	-1.50869965	0.48925919
295	296	297	298	299	302
0.80685775	-0.94769654	0.30140368	0.58011798	0.24101173	-0.76700125
305	307	308	310	312	315
-1.34087339	0.37540515	-1.16083247	1.27739107	0.77216528	0.25494271
317	320	322	324	326	330
0.48233411	1.14809405	-0.83483623	0.64707753	0.37833175	0.98064542
331	334	337	340	341	343
0.35767461	-1.52239299	0.65285107	0.91265019	1.34190587	0.76389926
344	345	346	347	349	350
0.73809917	0.50443526	0.41615382	0.31727211	0.22123995	-1.69532129
352	353	354	355	356	359
-2.12151980	0.06599396	-0.63539061	0.62512847	-0.94457055	0.44429318
360	361	362	363	366	368
-1.00484242	0.79165904	0.21919169	0.82154575	0.24290014	1.38768214

```
       369        371        372        375        376        378 
-0.81147686  0.46289861  0.36079797 -0.26435426 -0.74438017  0.30907600 
       383        384        385        388        389        392 
 0.71775013  0.76757079  0.55462777  0.66005878  0.48365189  0.41902753 
       393        394        396        397        399        400 
 1.35127025  0.46300971  1.72566368  1.06983155 -1.42630069  0.19708431 
       403        404        409        411        412        413 
-1.45214533  0.73780869  0.43336537  1.18621358  0.16616668 -2.49475279 
       415        417        418        420        421        423 
-1.03945472 -0.77837582  1.41930666 -1.37669719  0.51024354  0.40503235 
       424        426        427        428        429        433 
 0.24414512  0.48387125  0.47252142  0.12040749  0.28845132  0.52352184 
       435        436        437        438        440        442 
 0.67089767 -2.55174224  0.37305800  0.29741909 -1.58959481  1.24561423 
       444        448        449        454        455        456 
-1.29067059  0.26939858  0.17507147  0.27226539 -0.96367408  0.45172766 
       458        459        461        467        470        471 
-1.67592838  1.43839020  0.63223019 -0.68829900  0.26111935 -1.12223469 
       472        475        476        477        478        479 
-0.65199980 -1.76328599 -0.66069646  0.37076908  0.80649025  0.44224778 
       480        483        484        485        486        487 
 0.73827145  1.11071114  0.25091516  0.23074367 -1.67349412  0.25496228 
       488        490        491        492        493        497 
 1.56387835  0.43845092  0.27857178 -0.67462236  0.20962751 -0.65222734 
       499        500        501        502        503        505 
 0.64070388  0.47984595 -0.45095929  1.21281975  0.33952068 -0.41146712 
       506        512        513        514        515        517 
-2.60003358  0.25644739  0.41398411  1.32806884  0.57665701  0.66405961 
       519        523        525        526        527        530 
 1.02436547 -0.43140114  0.69077622  0.80470256  0.63436379  1.03818167 
       531        534        535        537        538        539 
 1.27229983  0.44399031  0.45215652  0.72477944  0.66570123 -0.33461756 
       540        541        542        544        545        546 
 0.66799949 -1.67506690  0.88012075 -2.33191031  0.37365273 -0.76886895 
       547        549        550        553        554        555 
 0.60089871 -0.95235048  0.17138690 -1.90110866  0.95781259  0.74686988 
       557        558        559        561        563        565 
-0.54724250 -1.62349998 -1.09599189  0.83113570  0.71449080  0.65050298 
       567        568        569        570        571        573 
-1.24786076  0.16275426  0.67514066 -0.76698791 -0.85417044  0.23575863 
       574        576        578        579        581        583 
 1.44290497  0.49413023  0.31459517 -0.88726946 -2.06122386  0.59160600 
       585        586        589        590        592        594 
 0.52993720 -1.30672685 -1.28862909 -1.89843689  1.15273826 -0.85200831 
       595        597        598        600        601        602 
-1.35030344 -0.58216627 -1.70594254  0.52277949  0.37339065 -1.44661218 
```

```
        603         604         606         607         608         612 
-0.54079114 -1.93628430  1.01230862  0.16548569 -0.72702051 -1.49813426 
        614         615         616         617         618         620 
 0.77061541 -2.07401659  1.30253511  0.94891761  0.78394476  0.62023322 
        621         625         626         627         629         630 
 0.46353939 -1.21750663  0.34681135  0.19445205  0.24674001  0.22718818 
        632         633         635         636         637         640 
-1.05297614  0.63443719 -0.96964723  0.91177674  0.54321220 -0.94642238 
        641         642         643         646         649         650 
-0.90596601  1.13466379 -2.16150944 -1.48324228 -1.19488506 -0.72346344 
        651         653         654         655         657         658 
 1.73625177 -0.66034984 -1.19392405  0.15801378 -0.83277017  0.64636745 
        662         663         665         666         667         668 
-1.19630397  0.42851514  0.42191704  0.87437836  0.82892642  0.83941054 
        669         670         672         673         674         675 
-0.83108913  0.49710284  0.42202140  1.04998991  0.30105762 -1.61177524 
        678         679         681         683         684         691 
-0.94781960  1.38214472  0.63625679  0.61369541  0.55290035  0.59037445 
        693         694         695         698         700         701 
 0.79046973  0.50532072  0.39120627  0.32845743  0.77853339 -1.82780462 
        703         705         706         708         709         710 
 0.81073544  1.57289839  0.90920454 -0.54288547  0.94800833  0.51223809 
        712         714         715         716         717         719 
-0.45713770  0.53017150 -0.54316526  0.12675770  0.23109643  0.17239592 
        720         722         726         728         730         731 
 1.35208437 -0.66447965  0.19574254 -0.65098200  0.12641667  0.92917190 
        735         736         737         739         742         744 
 0.31678592  1.60500400 -1.40087146  0.24691306  0.87985831  0.99049628 
        745         746         747         748         749         751 
 0.74966262  1.03439369  1.60745314 -0.89569030  0.14628173  0.90225474 
        752         754         755         756         757         758 
-0.92479851  0.61917490 -1.95302026 -0.91122416  0.15535924 -2.96863698 
        759         761         763         764         766         767 
 0.21782112  0.25738567  1.07396601 -1.78616461  0.58422773 -1.05334445 
        769         770         773         774         775         777 
 0.41276068  0.13410559  0.09963273  0.44665004  0.36827162  0.47063281 
        778         784         785         788         790         791 
 0.79899331 -0.68096714  0.16689341  0.21232407 -0.74105984 -1.18857035 
        792         794         795         798         799         800 
 0.21066476  0.82205477  0.62481707  0.44754157  0.54876164  0.60419488 
        803         804         805         806         808         809 
 0.83736578  0.19939165  0.88525707 -0.85847378  0.13286953  0.80733767 
        812         813         818         820         821         822 
 0.39794865 -1.65881596  0.20886824 -1.10436316  0.48119373  0.63291696 
        825         827         828         829         831         834 
 0.30424501 -1.16473376 -1.30949017 -1.42686141  0.54557364  0.62413971 
```

```
       835         837         838         841         843         844
-1.99334056  0.38573194  0.46800350 -1.07442513 -1.47563999  0.57352129
       845         848         849         850         851         854
 0.69906876  0.95795943  0.49165099 -1.39974974 -1.13595370 -0.63014344
       855         856         857         859         862         863
 1.31015041  0.75177921  0.32616390 -0.84132638 -1.78960999 -1.11455204
       864         866         868         872         875         876
 0.27869581  0.51529861  0.30961598  0.24165664  1.27222035  0.57591314
       877         879         881         885         886         887
 1.58191114 -1.17176081  0.23724247 -1.72710610 -0.68470330  0.40635110
       888         889         890         891         893         894
-0.74207728  0.65695310  0.32009468  1.02125191  1.07089308  0.39525224
       895         896         899         900         901         902
 0.15026935  0.29677044  0.23496467 -1.23544064 -1.65670168  0.23328267
       904         906         909         910         911         914
 0.28701137  0.58090699  0.36087269  0.51081011  0.80706815  0.17105163
       915         916         917         919         921         922
-0.81943340 -0.34411669  0.23309525 -1.51826681  0.46908333  0.76635887
       923         924         930         932         933         934
-0.84847660  1.05625352  1.34761269 -1.28531996  0.28893871  0.26698293
       935         936         938         939         941         942
 1.53309477 -1.20608706  0.97846318 -0.51605688  0.30969593  0.46926446
       943         944         945         947         948         949
 0.24226079  0.23002836  1.25267918 -0.80500187  0.33699978 -1.20461581
       951         952         955         958         960         961
 0.71459651 -1.53755862  1.12200181  0.30623929  1.16031268  0.31075935
       962         964         965         966         968         970
 0.96869881 -2.12397630  1.18530215  0.81680090  0.82618611  0.67144014
       971         972         974         975         977         978
 0.53023410  0.79090669 -0.23520975  0.45662335  0.28260660  0.74966711
       979         980         981         984         985         986
-1.22359937 -0.96775859 -1.99555852 -1.21604779  0.19725846  1.13222746
       987         988         993         994         997         998
 1.61956530  0.29464690  0.70837795  1.00968580  0.76624459  0.49362119

>
```

Using the model with the test data

The test data is then run through the model

```
> p.test <- predict(logit, gc.test, type="response")
> summary(p.test)

   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
0.03299 0.56790 0.80110 0.71260 0.92580 0.99650
```

Classification Table

A baseline Classification Table with cutoff = 50% is given

```
> library(gmodels)
> p.test.vals <- sapply(p.test, function(y) { ifelse(y<.5,0, 1) })
> CrossTable(gc.test$RESPONSE, p.test.vals, dnn = c("Actual", "Predicted"))
```

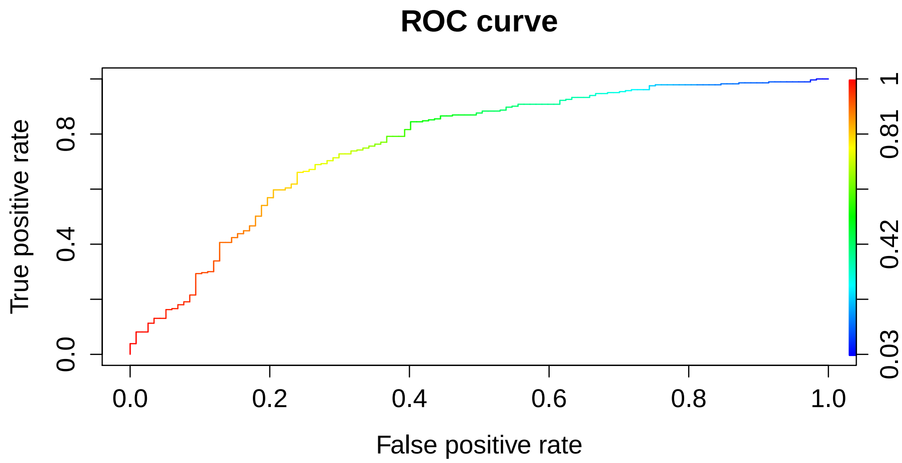
```
   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted 
      Actual |         0 |         1 | Row Total | 
-------------|-----------|-----------|-----------|
           0 |        52 |        73 |       125 | 
             |    28.137 |     7.145 |           | 
             |     0.416 |     0.584 |     0.312 | 
             |     0.642 |     0.229 |           | 
             |     0.130 |     0.182 |           | 
-------------|-----------|-----------|-----------|
           1 |        29 |       246 |       275 | 
             |    12.790 |     3.248 |           | 
             |     0.105 |     0.895 |     0.688 | 
             |     0.358 |     0.771 |           | 
             |     0.072 |     0.615 |           | 
-------------|-----------|-----------|-----------|
Column Total |        81 |       319 |       400 | 
             |     0.203 |     0.797 |           | 
-------------|-----------|-----------|-----------|
```

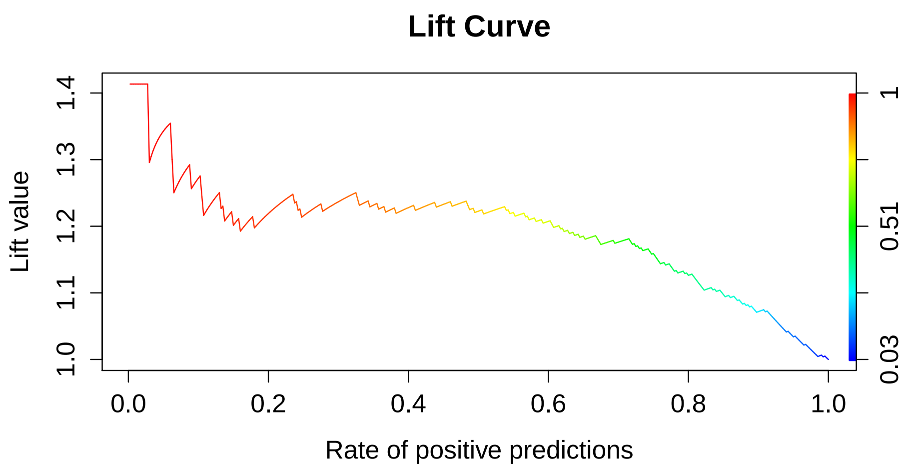
ROC Curve

```
> library(ROCR)
> p.rocr <- prediction(p.test, gc.test$RESPONSE)
> p.rocr.roc <- performance(p.rocr, "tpr", "fpr")
> plot(p.rocr.roc, main="ROC Curve", colorize=T)
```



Lift Curve

```
> p.rocr.lift <- performance(p.rocr, "lift", "rpp")
> plot(p.rocr.lift, main="Lift Curve", colorize=T)
```



0.1 Classification Table with different cutoff values

```
> calcNetProfit <- function(facts, preds, cutoff) {
+   vals <- sapply(preds, function(y) { ifelse(y<cutoff,0, 1) })
+   ct <- CrossTable(facts, vals, dnn = c("Actual", "Predicted"))
+   print("Profit with cutoff")
+   print(cutoff)
```

```
+   profitFromCrossTable(ct)
+ }
> profitFromCrossTable <- function(ct) {
+   profit <- ct$t[1,1] * 100
+   loss <- ct$t[2,1] * -500
+   profit - loss
+ }
> s <- seq(0,1, by = .1)
> for(i in s) { print(calcNetProfit(gc.test$RESPONSE, p.test, i)) }
```

```
   Cell Contents
|-------------------------|
|                       N |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | vals
       facts |         1 | Row Total |
-------------|-----------|-----------|
           0 |       125 |       125 |
             |     0.312 |           |
-------------|-----------|-----------|
           1 |       275 |       275 |
             |     0.688 |           |
-------------|-----------|-----------|
Column Total |       400 |       400 |
-------------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0
[1] 150000


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|
```

```
Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |         5 |       120 |       125 |
             |     3.616 |     0.064 |           |
             |     0.040 |     0.960 |     0.312 |
             |     0.714 |     0.305 |           |
             |     0.013 |     0.300 |           |
-------------|-----------|-----------|-----------|
           1 |         2 |       273 |       275 |
             |     1.644 |     0.029 |           |
             |     0.007 |     0.993 |     0.688 |
             |     0.286 |     0.695 |           |
             |     0.005 |     0.682 |           |
-------------|-----------|-----------|-----------|
Column Total |         7 |       393 |       400 |
             |     0.018 |     0.983 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.1
[1] 1500


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
```

```
            0 |        16 |       109 |       125 | 
              |    12.111 |     0.705 |           | 
              |     0.128 |     0.872 |     0.312 | 
              |     0.727 |     0.288 |           | 
              |     0.040 |     0.273 |           | 
-------------|-----------|-----------|-----------|
            1 |         6 |       269 |       275 | 
              |     5.505 |     0.320 |           | 
              |     0.022 |     0.978 |     0.688 | 
              |     0.273 |     0.712 |           | 
              |     0.015 |     0.672 |           | 
-------------|-----------|-----------|-----------|
Column Total |        22 |       378 |       400 | 
              |     0.055 |     0.945 |           | 
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.2
[1] 4600


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted 
      Actual |         0 |         1 | Row Total | 
-------------|-----------|-----------|-----------|
           0 |        32 |        93 |       125 | 
             |    25.642 |     3.089 |           | 
             |     0.256 |     0.744 |     0.312 | 
             |     0.744 |     0.261 |           | 
             |     0.080 |     0.233 |           | 
-------------|-----------|-----------|-----------|
           1 |        11 |       264 |       275 | 
             |    11.656 |     1.404 |           | 
```

```
             |     0.040 |     0.960 |     0.688 |
             |     0.256 |     0.739 |           |
             |     0.028 |     0.660 |           |
-------------|-----------|-----------|-----------|
Column Total |        43 |       357 |       400 |
             |     0.107 |     0.892 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.3
[1] 8700


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |        46 |        79 |       125 |
             |    32.485 |     6.303 |           |
             |     0.368 |     0.632 |     0.312 |
             |     0.708 |     0.236 |           |
             |     0.115 |     0.198 |           |
-------------|-----------|-----------|-----------|
           1 |        19 |       256 |       275 |
             |    14.766 |     2.865 |           |
             |     0.069 |     0.931 |     0.688 |
             |     0.292 |     0.764 |           |
             |     0.048 |     0.640 |           |
-------------|-----------|-----------|-----------|
Column Total |        65 |       335 |       400 |
             |     0.163 |     0.838 |           |
-------------|-----------|-----------|-----------|
```

```
[1] "Profit with cutoff"
[1] 0.4
[1] 14100


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |        52 |        73 |       125 |
             |    28.137 |     7.145 |           |
             |     0.416 |     0.584 |     0.312 |
             |     0.642 |     0.229 |           |
             |     0.130 |     0.182 |           |
-------------|-----------|-----------|-----------|
           1 |        29 |       246 |       275 |
             |    12.790 |     3.248 |           |
             |     0.105 |     0.895 |     0.688 |
             |     0.358 |     0.771 |           |
             |     0.072 |     0.615 |           |
-------------|-----------|-----------|-----------|
Column Total |        81 |       319 |       400 |
             |     0.203 |     0.797 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.5
[1] 19700


   Cell Contents
|-------------------------|
```

```
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |        73 |        52 |       125 |
             |    35.390 |    14.809 |           |
             |     0.584 |     0.416 |     0.312 |
             |     0.619 |     0.184 |           |
             |     0.182 |     0.130 |           |
-------------|-----------|-----------|-----------|
           1 |        45 |       230 |       275 |
             |    16.086 |     6.731 |           |
             |     0.164 |     0.836 |     0.688 |
             |     0.381 |     0.816 |           |
             |     0.113 |     0.575 |           |
-------------|-----------|-----------|-----------|
Column Total |       118 |       282 |       400 |
             |     0.295 |     0.705 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.6
[1] 29800


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|
```

```
Total Observations in Table:  400


             | Predicted 
      Actual |         0 |         1 | Row Total | 
-------------|-----------|-----------|-----------|
           0 |        86 |        39 |       125 | 
             |    26.538 |    17.508 |           | 
             |     0.688 |     0.312 |     0.312 | 
             |     0.541 |     0.162 |           | 
             |     0.215 |     0.098 |           | 
-------------|-----------|-----------|-----------|
           1 |        73 |       202 |       275 | 
             |    12.063 |     7.958 |           | 
             |     0.265 |     0.735 |     0.688 | 
             |     0.459 |     0.838 |           | 
             |     0.182 |     0.505 |           | 
-------------|-----------|-----------|-----------|
Column Total |       159 |       241 |       400 | 
             |     0.398 |     0.603 |           | 
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.7
[1] 45100


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted 
      Actual |         0 |         1 | Row Total | 
-------------|-----------|-----------|-----------|
           0 |       100 |        25 |       125 | 
             |    22.992 |    22.763 |           | 
```

```
             |     0.800 |     0.200 |     0.312 |
             |     0.503 |     0.124 |           |
             |     0.250 |     0.062 |           |
-------------|-----------|-----------|-----------|
           1 |        99 |       176 |       275 |
             |    10.451 |    10.347 |           |
             |     0.360 |     0.640 |     0.688 |
             |     0.497 |     0.876 |           |
             |     0.247 |     0.440 |           |
-------------|-----------|-----------|-----------|
Column Total |       199 |       201 |       400 |
             |     0.497 |     0.502 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.8
[1] 59500


   Cell Contents
|-------------------------|
|                       N |
| Chi-square contribution |
|           N / Row Total |
|           N / Col Total |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | Predicted
      Actual |         0 |         1 | Row Total |
-------------|-----------|-----------|-----------|
           0 |       113 |        12 |       125 |
             |     8.986 |    19.316 |           |
             |     0.904 |     0.096 |     0.312 |
             |     0.414 |     0.094 |           |
             |     0.282 |     0.030 |           |
-------------|-----------|-----------|-----------|
           1 |       160 |       115 |       275 |
             |     4.084 |     8.780 |           |
             |     0.582 |     0.418 |     0.688 |
             |     0.586 |     0.906 |           |
```

```
             |     0.400 |     0.287 |           |
-------------|-----------|-----------|-----------|
Column Total |       273 |       127 |       400 |
             |     0.682 |     0.318 |           |
-------------|-----------|-----------|-----------|


[1] "Profit with cutoff"
[1] 0.9
[1] 91300


   Cell Contents
|-------------------------|
|                       N |
|         N / Table Total |
|-------------------------|


Total Observations in Table:  400


             | vals
       facts |         0 | Row Total |
-------------|-----------|-----------|
           0 |       125 |       125 |
             |     0.312 |           |
-------------|-----------|-----------|
           1 |       275 |       275 |
             |     0.688 |           |
-------------|-----------|-----------|
Column Total |       400 |       400 |
-------------|-----------|-----------|


[1] "Profit with cutoff"
[1] 1
[1] 150000
```

Lesson 3 Question and Answer

1

Comments on the models

2

If you want to select 275 customers from the validation data set, which model would you adopt for credit rating? Why?

With a value for k too small we will classify in a way that is very sensitive to the local characteristcs of the training data.

With a value of k too large we essentially overfit, ignoring the information contained in the predictor variables. In the extreme with k equal the number of observations in the train data all test data is assigned to the most frequent class in the train data, Owner in the present case.