Appendix R code and output

Appendix 1. Anova table of model 2

Response: target

	LR Chisq	Df	Pr(>Chisq)	
sex	10.938	1	0.0009422	***
cp	13.282	2	0.0013060	**
trestbps	4.592	1	0.0321253	*
chol	0.971	1	0.3243812	
fbs	4.987	1	0.0255352	*
thalach	0.546	1	0.4598773	
exang	4.806	1	0.0283614	*
slope	14.386	1	0.0001489	***
ca	37.765	1	7.979e-10	***
thal	10.674	1	0.0010867	**
exang:slope	6.779	1	0.0092261	**
sex:fbs	9.403	1	0.0021666	**
fbs:slope	10.029	1	0.0015413	**
exang:ca	10.005	1	0.0015608	**
trestbps:exang	6.184	1	0.0128931	*
thalach:ca	5.871	1	0.0153966	*
fbs:ca	2.729	1	0.0985694	.
thalach:exang	2.180	1	0.1398572	
sex:thal	4.079	1	0.0434178	*
cp:chol	5.510	2	0.0635985	.

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Appendix 2. odds ratio of final model

	coefficient	95%CI(2.5%)	95%CI(97.5.5%)	odds ratio
(Intercept)	" -1.96"	" -6.23"	" 2.22"	" 0.14"
sexM	" 0.14"	" -2.31"	" 2.38"	" 1.15"
cpasymptomatic	" 1.43"	" 0.49"	" 2.43"	" 4.19"
cpnon_anginal	" -0.14"	" -1.22"	" 0.91"	" 0.87"
trestbps	" 0.01"	" -0.01"	" 0.04"	" 1.01"
fbsTrue	" 6.10"	" 1.41"	" 11.12"	"447.51"
exangYes	" -6.48"	"-13.83"	" 0.14"	" 0.00"
slopeup	" -0.85"	" -1.79"	" 0.07"	" 0.43"
ca	" 1.25"	" 0.69"	" 1.89"	" 3.49"
thalnormal	" -3.22"	" -5.83"	" -0.92"	" 0.04"
exangYes:slopeup	" -2.34"	" -4.51"	" -0.41"	" 0.10"
sexM:fbsTrue	" -7.79"	"-13.28"	" -2.86"	" 0.00"
fbsTrue:slopeup	" -7.29"	"-14.57"	" -1.56"	" 0.00"
exangYes:ca	" 2.43"	" 0.59"	" 4.73"	" 11.41"
trestbps:exangYes	" 0.06"	" 0.01"	" 0.12"	" 1.06"
fbsTrue:ca	" 1.80"	" -0.44"	" 4.58"	" 6.03"
sexM:thalnormal	" 2.02"	" -0.44"	" 4.78"	" 7.52"

Appendix: Ready to run R code

```
setwd("~/Desktop")
#step1. take a look at the dataset
#read CSV file
heart1=read.table("project.1.data.1.csv",sep=",",head=T)
#preview of data
heart1[1:10,]
#check variable type
str(heart1)
#step2. Data cleaning
summary(heart1)
#change categorical variable to factor
heart1$sex[heart1$sex==1]="M"
heart1$sex[heart1$sex==0]="F"
heart1$sex=as.factor(heart1$sex)
heart1$fbs[heart1$fbs==1]="True"
heart1$fbs[heart1$fbs==0]="False"
heart1$fbs=as.factor(heart1$fbs)
heart1$cp[heart1$cp==1]="typical"
heart1$cp[heart1$cp==2]="atypical"
heart1$cp[heart1$cp==3]="non_anginal"
heart1$cp[heart1$cp==4]="ymptomatic"
heart1$cp=as.factor(heart1$cp)
heart1$exang[heart1$exang==1]="Yes"
heart1$exang[heart1$exang==0]="No"
heart1$exang=as.factor(heart1$exang)
heart1$restecg[heart1$restecg==0]="normal"
heart1$restecg[heart1$restecg==1]="ST_T_abnormal"
heart1$restecg[heart1$restecg==2]="probable or definite left ventricular hypertrophy"
heart1$restecg=as.factor(heart1$restecg)
heart1$thal[heart1$thal==3]="normal"
heart1$thal[heart1$thal==6]="fixed_defect"
heart1$thal[heart1$thal==7]="reversable_defect"
heart1$thal=as.factor(heart1$thal)
heart1$slope[heart1$slope==1]="up"
heart1$slope[heart1$slope==2]="flat"
heart1$slope[heart1$slope==3]="down"
heart1$slope=as.factor(heart1$slope)
heart1$target=as.factor(heart1$target)
str(heart1)
#step3. Visuals
```

Figure 2b.

```
#graph numeric variables vs. "target"
boxplot(age~target,data=heart1,xlab="Heart Disease",ylab="Age")
boxplot(trestbps~target,data=heart1,xlab="Heart Disease",ylab="resting blood pressure (in mm Hg) ")
boxplot(chol~target,data=heart1,xlab="Heart Disease",ylab="serum cholestoral in mg/dl")
boxplot(thalach~target,data=heart1,xlab="Heart Disease",ylab="maximum heart rate achieved")
boxplot(oldpeak~target,data=heart1,xlab="Heart Disease",ylab="ST depression induced by exercise relative to
rest")
boxplot(ca~target,data=heart1,xlab="Heart Disease",ylab="number of major vessels(0-3)")
#graph categorical variable vs. "target"
```

Figure 1.

```
plot(heart1$target, xlab="heart disease", ylab="count")
```

```
spineplot(target~sex,data=heart1,ylab="Heart Disease",xlab="Sex")
spineplot(target~cp,data=heart1,ylab="Heart Disease",xlab="chest pain type")
spineplot(target~fbs,data=heart1,ylab="Heart Disease",xlab="fasting blood sugar > 120 mg/dl")
spineplot(target~restecg,data=heart1,ylab="Heart Disease",xlab="resting electrocardiographic")
spineplot(target~exang,data=heart1,ylab="Heart Disease",xlab="exercise induced angina")
spineplot(target~slope,data=heart1,ylab="Heart Disease",xlab="slope of the peak exercise ST segment")
spineplot(target~thal,data=heart1,ylab="Heart Disease",xlab="thal")

#Combine data with few observations
heart1=read.table("project.1.data.1.csv",sep=",",head=T)

plot(heart1$sex)
heart1$sex[heart1$sex==1]="M"
heart1$sex[heart1$sex==0]="F"
heart1$sex=as.factor(heart1$sex)

plot(heart1$fbs)
heart1$fbs[heart1$fbs==1]="True"
heart1$fbs[heart1$fbs==0]="False"
heart1$fbs=as.factor(heart1$fbs)

#combine typical and atypical angina as one
plot(heart1$cp)
heart1$cp[heart1$cp==1]="angina"
heart1$cp[heart1$cp==2]="angina"
heart1$cp[heart1$cp==3]="non_anginal"
heart1$cp[heart1$cp==4]="asymptomatic"
heart1$cp=as.factor(heart1$cp)

plot(heart1$exang)
heart1$exang[heart1$exang==1]="Yes"
heart1$exang[heart1$exang==0]="No"
heart1$exang=as.factor(heart1$exang)

#combine ST_T_abnormal and "probable or definite left ventricular hypertrophy" as abnormal
plot(heart1$restecg)
heart1$restecg[heart1$restecg==0]="normal"
heart1$restecg[heart1$restecg==1]="abnormal"
heart1$restecg[heart1$restecg==2]="abnormal"
heart1$restecg=as.factor(heart1$restecg)

#combine fixed and reversable defect as defect
plot(heart1$thal)
heart1$thal[heart1$thal==3]="normal"
heart1$thal[heart1$thal==6]="defect"
heart1$thal[heart1$thal==7]="defect"
heart1$thal=as.factor(heart1$thal)

#combine flat and down together
plot(heart1$slope)
heart1$slope[heart1$slope==1]="up"
heart1$slope[heart1$slope==2]="flat|down"
heart1$slope[heart1$slope==3]="flat|down"
heart1$slope=as.factor(heart1$slope)
heart1$target=as.factor(heart1$target)
```

Figure 2a.

```
#graph categorical variable vs. "target"
plot(heart1$target, xlab="heart disease", ylab="count")
spineplot(target~sex,data=heart1,ylab="Heart Disease",xlab="Sex")
spineplot(target~cp,data=heart1,ylab="Heart Disease",xlab="chest pain type")
spineplot(target~fbs,data=heart1,ylab="Heart Disease",xlab="fasting blood sugar > 120 mg/dl")
spineplot(target~restecg,data=heart1,ylab="Heart Disease",xlab="resting electrocardiographic")
spineplot(target~exang,data=heart1,ylab="Heart Disease",xlab="exercise induced angina")
spineplot(target~slope,data=heart1,ylab="Heart Disease",xlab="slope of the peak exercise ST segment")
spineplot(target~thal,data=heart1,ylab="Heart Disease",xlab="Thalassemia")
```

```
#step 4.model selection
```

Model. 1

```
#model selection without interaction
fit.1=glm(target~1,data=heart1,family="binomial")
fit.2=glm(target~.,data=heart1,family="binomial")
select.1=step(fit.2, scope=list(lower=fit.1,upper=fit.2),direction="backward")
summary(select.1)
coef(select.1)
```

Model. 2

```
#model selection with interaction
fit.3=glm(target ~ (sex + cp + trestbps + chol + fbs + thalach + exang + slope + ca + thal)^2, family = "binomial",
data = heart1)
select.2=step(select.1, scope=list(lower=select.1,upper=fit.3),direction="forward")
summary(select.2)
coef(select.2)
```

Final model

```
library(car)# Anova
Anova(select.2) #based on this, exang not significant remove exang in fit.4
fit.final=glm(target ~ sex + cp + trestbps  + fbs  + exang + slope + ca + thal + exang:slope + sex:fbs + fbs:slope +
exang:ca + trestbps:exang  + fbs:ca + sex:thal,
          data=heart1, family=binomial)
summary(fit.final)
coef(fit.final)
confint(fit.final) #likelihood ratio CI
Anova(fit.final)
```

Final model. Odds ratio

```
oddsratio=cbind(coef(fit.final),confint(fit.final),exp(coef(fit.final)))
colnames(oddsratio)=c("coefficient","95%CI(2.5%)","95%CI(97.5.5%)","odds ratio")
oddsratio=format(round(oddsratio,2), nsmall=2)
oddsratio
```

ROC AUC

```
#step 5. model evalution: sensitivity/specificity/ROC/AUC
pi0=seq(1,0, length.out = 100)
nsample=nrow(heart1)
roc=NULL
```

```
cv.set.list=split(sample(nsample),rep(1:10,length=nsample))  #10-fold cross-validation method
for(k in 1:length(pi0))
{n_11=n_10=n_01=n_00=0
nsample=nrow(heart1)
for(i in 1:length(cv.set.list))
{
  training=heart1[-cv.set.list[[i]],]
  test=heart1[cv.set.list[[i]],]
  fit.training=glm(target ~ sex + cp + trestbps  + fbs  + exang + slope + ca + thal + exang:slope + sex:fbs +
fbs:slope +
                   exang:ca + trestbps:exang  + fbs:ca + sex:thal, data=training, family="binomial")
  for(j in 1:length(cv.set.list[[i]]))
  {if(predict(fit.training, test[j,], type="response")>=pi0[k])
  {Y.pred.1=1}else{Y.pred.1=0}
    if((test$target[j]==1)&(Y.pred.1==1))
    {n_11=n_11+1}
    if((test$target[j]==1)&(Y.pred.1==0))
    {n_10=n_10+1}
    if((test$target[j]==0)&(Y.pred.1==1))
    {n_01=n_01+1}
    if((test$target[j]==0)&(Y.pred.1==0))
    {n_00=n_00+1}
  }
}
sen=n_11/(n_10+n_11)
spe=n_00/(n_00+n_01)
roc=rbind(roc, c(1-spe, sen))
}
plot(roc, type="s",xlim=c(0,1), ylim=c(0,1), col="red", main="ROC curve", xlab="1-Specificity",
ylab="Sensitivity")
auc=sum(roc[-100, 2]*(roc[-1,1]-roc[-100,1]))
auc #AUC area under ROC curve
pred.accuracy=roc[,2]*sum(heart1$target==1)/nsample+(1-roc[,1])*sum(heart1$target==0)/nsample
z.1=which.max(pred.accuracy)
pi0[z.1] #best cut-off points
pred.accuracy[z.1]  #best prediction accuracy
```

Appendix. output

```
> heart1$restecg[heart1$restecg==2]="probable or definite left ventricular hypertrophy"
> heart1$restecg=as.factor(heart1$restecg)
> heart1$thal[heart1$thal==3]="normal"
> heart1$thal[heart1$thal==6]="fixed_defect"
> heart1$thal[heart1$thal==7]="reversable_defect"
> heart1$thal=as.factor(heart1$thal)
> heart1$slope[heart1$slope==1]="up"
> heart1$slope[heart1$slope==2]="flat"
> heart1$slope[heart1$slope==3]="down"
> heart1$slope=as.factor(heart1$slope)
> heart1$target=as.factor(heart1$target)
> str(heart1)
'data.frame':        297 obs. of  14 variables:
 $ age     : int  63 67 67 37 41 56 62 57 63 53 ...
```

```
 $ sex     : Factor w/ 2 levels "F","M": 2 2 2 2 1 2 1 1 2 2 ...
 $ cp      : Factor w/ 4 levels "atypical","non_anginal",..: 3 4 4 2 1 1 4 4 4 4 ...
 $ trestbps: int  145 160 120 130 130 120 140 120 130 140 ...
 $ chol    : int  233 286 229 250 204 236 268 354 254 203 ...
 $ fbs     : Factor w/ 2 levels "False","True": 2 1 1 1 1 1 1 1 1 2 ...
 $ restecg : Factor w/ 3 levels "normal","probable or definite left ventricular hypertrophy",..: 2 2 2 1 2 1 2 1 2
2 ...
 $ thalach : int  150 108 129 187 172 178 160 163 147 155 ...
 $ exang   : Factor w/ 2 levels "No","Yes": 1 2 2 1 1 1 1 2 1 2 ...
 $ oldpeak : num  2.3 1.5 2.6 3.5 1.4 0.8 3.6 0.6 1.4 3.1 ...
 $ slope   : Factor w/ 3 levels "down","flat",..: 1 2 2 1 3 3 1 3 2 1 ...
 $ ca      : int  0 3 2 0 0 0 2 0 1 0 ...
 $ thal    : Factor w/ 3 levels "fixed_defect",..: 1 2 3 2 2 2 2 2 3 3 ...
 $ target  : Factor w/ 2 levels "0","1": 1 2 2 1 1 1 2 1 2 2 ...
> #step3. Visuals
```

Figure 2b

```
> #graph numeric variables vs. "target"
> boxplot(age~target,data=heart1,xlab="Heart Disease",ylab="Age")
> boxplot(trestbps~target,data=heart1,xlab="Heart Disease",ylab="resting blood pressure (in mm Hg) ")
> boxplot(chol~target,data=heart1,xlab="Heart Disease",ylab="serum cholestoral in mg/dl")
> boxplot(thalach~target,data=heart1,xlab="Heart Disease",ylab="maximum heart rate achieved")
> boxplot(oldpeak~target,data=heart1,xlab="Heart Disease",ylab="ST depression induced by exercise relative
to rest")
> boxplot(ca~target,data=heart1,xlab="Heart Disease",ylab="number of major vessels(0-3)")
> #graph categorical variable vs. "target"
> plot(heart1$target, xlab="heart disease", ylab="count")
```

Figure 1

```
> spineplot(target~sex,data=heart1,ylab="Heart Disease",xlab="Sex")
> spineplot(target~cp,data=heart1,ylab="Heart Disease",xlab="chest pain type")
> spineplot(target~fbs,data=heart1,ylab="Heart Disease",xlab="fasting blood sugar > 120 mg/dl")
> spineplot(target~restecg,data=heart1,ylab="Heart Disease",xlab="resting electrocardiographic")
> spineplot(target~exang,data=heart1,ylab="Heart Disease",xlab="exercise induced angina")
> spineplot(target~slope,data=heart1,ylab="Heart Disease",xlab="slope of the peak exercise ST segment")
> spineplot(target~thal,data=heart1,ylab="Heart Disease",xlab="thal")
>
```

```
> #Combine data with few observations
> heart1=read.table("project.1.data.1.csv",sep=",",head=T)
>
> plot(heart1$sex)
> heart1$sex[heart1$sex==1]="M"
> heart1$sex[heart1$sex==0]="F"
> heart1$sex=as.factor(heart1$sex)
>
> plot(heart1$fbs)
> heart1$fbs[heart1$fbs==1]="True"
> heart1$fbs[heart1$fbs==0]="False"
> heart1$fbs=as.factor(heart1$fbs)
>
> #combine typical and atypical angina as one
> plot(heart1$cp)
```

```
> heart1$cp[heart1$cp==1]="angina"
> heart1$cp[heart1$cp==2]="angina"
> heart1$cp[heart1$cp==3]="non_anginal"
> heart1$cp[heart1$cp==4]="asymptomatic"
> heart1$cp=as.factor(heart1$cp)
>
> plot(heart1$exang)
> heart1$exang[heart1$exang==1]="Yes"
> heart1$exang[heart1$exang==0]="No"
> heart1$exang=as.factor(heart1$exang)
>
> #combine ST_T_abnormal and "probable or definite left ventricular hypertrophy" as abnormal
> plot(heart1$restecg)
> heart1$restecg[heart1$restecg==0]="normal"
> heart1$restecg[heart1$restecg==1]="abnormal"
> heart1$restecg[heart1$restecg==2]="abnormal"
> heart1$restecg=as.factor(heart1$restecg)
>
> #combine fixed and reversable defect as defect
> plot(heart1$thal)
> heart1$thal[heart1$thal==3]="normal"
> heart1$thal[heart1$thal==6]="defect"
> heart1$thal[heart1$thal==7]="defect"
> heart1$thal=as.factor(heart1$thal)
>
> #combine flat and down together
> plot(heart1$slope)
> heart1$slope[heart1$slope==1]="up"
> heart1$slope[heart1$slope==2]="flat|down"
> heart1$slope[heart1$slope==3]="flat|down"
> heart1$slope=as.factor(heart1$slope)
> heart1$target=as.factor(heart1$target)
```

Figure 2a

```
> #graph categorical variable vs. "target"
> plot(heart1$target, xlab="heart disease", ylab="count")
> spineplot(target~sex,data=heart1,ylab="Heart Disease",xlab="Sex")
> spineplot(target~cp,data=heart1,ylab="Heart Disease",xlab="chest pain type")
> spineplot(target~fbs,data=heart1,ylab="Heart Disease",xlab="fasting blood sugar > 120 mg/dl")
> spineplot(target~restecg,data=heart1,ylab="Heart Disease",xlab="resting electrocardiographic")
> spineplot(target~exang,data=heart1,ylab="Heart Disease",xlab="exercise induced angina")
> spineplot(target~slope,data=heart1,ylab="Heart Disease",xlab="slope of the peak exercise ST segment")
> spineplot(target~thal,data=heart1,ylab="Heart Disease",xlab="Thalassemia")
```

> #**step 4.model selection**

model 1 selection

```
> #model selection without interaction
> fit.1=glm(target~1,data=heart1,family="binomial")
> fit.2=glm(target~.,data=heart1,family="binomial")
> select.1=step(fit.2, scope=list(lower=fit.1,upper=fit.2),direction="backward")
Start:  AIC=227.57
target ~ age + sex + cp + trestbps + chol + fbs + restecg + thalach +
    exang + oldpeak + slope + ca + thal
```

```
         Df Deviance    AIC
- age      1   197.92 225.92
- oldpeak  1   198.85 226.85
- restecg  1   198.97 226.97
<none>         197.57 227.57
- fbs      1   199.71 227.71
- chol     1   199.75 227.75
- thalach  1   200.16 228.16
- exang    1   200.52 228.52
- trestbps 1   201.81 229.81
- slope    1   202.03 230.03
- sex      1   205.32 233.32
- thal     1   206.75 234.75
- cp       2   213.38 239.38
- ca       1   226.66 254.66

Step:  AIC=225.92
target ~ sex + cp + trestbps + chol + fbs + restecg + thalach +
    exang + oldpeak + slope + ca + thal

         Df Deviance    AIC
- restecg  1   199.29 225.29
- oldpeak  1   199.30 225.30
- chol     1   199.90 225.90
<none>         197.92 225.92
- fbs      1   200.14 226.14
- thalach  1   200.17 226.17
- exang    1   200.96 226.96
- trestbps 1   201.81 227.81
- slope    1   202.24 228.24
- sex      1   206.19 232.19
- thal     1   207.01 233.01
- cp       2   214.17 238.17
- ca       1   227.54 253.54

Step:  AIC=225.29
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    oldpeak + slope + ca + thal

         Df Deviance    AIC
- oldpeak  1   200.60 224.60
<none>         199.29 225.29
- fbs      1   201.41 225.41
- thalach  1   201.61 225.61
- chol     1   201.96 225.96
- exang    1   202.41 226.41
- trestbps 1   203.65 227.65
- slope    1   204.41 228.41
- thal     1   207.71 231.71
- sex      1   208.79 232.79
- cp       2   215.53 237.53
- ca       1   229.65 253.65

Step:  AIC=224.6
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal
```

```
        Df Deviance    AIC
<none>         200.60 224.60
- fbs      1   202.92 224.92
- thalach  1   203.13 225.13
- chol     1   203.40 225.40
- exang    1   204.32 226.32
- trestbps 1   205.67 227.67
- thal     1   209.51 231.51
- slope    1   209.85 231.85
- sex      1   211.23 233.23
- cp       2   216.55 236.55
- ca       1   235.44 257.44
```

model 1

```
> summary(select.1)
Call:
glm(formula = target ~ sex + cp + trestbps + chol + fbs + thalach +
    exang + slope + ca + thal, family = "binomial", data = heart1)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-2.8956  -0.4994  -0.1579   0.4235   2.5855

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)    -3.802180   2.240935  -1.697  0.08975 .
sexM            1.550460   0.494219   3.137  0.00171 **
cpasymptomatic  1.380991   0.470005   2.938  0.00330 **
cpnon_anginal  -0.297578   0.507756  -0.586  0.55783
trestbps        0.022301   0.010149   2.197  0.02800 *
chol            0.006327   0.003736   1.693  0.09038 .
fbsTrue        -0.857185   0.570129  -1.503  0.13271
thalach        -0.015184   0.009723  -1.562  0.11838
exangYes        0.820650   0.423148   1.939  0.05245 .
slopeup        -1.223228   0.409763  -2.985  0.00283 **
ca              1.303097   0.252968   5.151 2.59e-07 ***
thalnormal     -1.171886   0.394730  -2.969  0.00299 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 409.95  on 296  degrees of freedom
Residual deviance: 200.60  on 285  degrees of freedom
AIC: 224.6

Number of Fisher Scoring iterations: 6

> coef(select.1)
  (Intercept)         sexM cpasymptomatic  cpnon_anginal      trestbps          chol       fbsTrue       thalach
 -3.802180287   1.550459839   1.380991253  -0.297578161   0.022300661   0.006326923  -0.857185090  -
0.015183944
     exangYes       slopeup            ca     thalnormal
  0.820650053  -1.223227874   1.303096651  -1.171886079
```

>

model 2 selection

```
> #model selection with interaction
> fit.3=glm(target ~ (sex + cp + trestbps + chol + fbs + thalach + exang + slope + ca + thal)^2, family =
"binomial", data = heart1)
> select.2=step(select.1, scope=list(lower=select.1,upper=fit.3),direction="forward")
Start:  AIC=224.6
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
   slope + ca + thal

                  Df Deviance    AIC
+ exang:slope      1   196.84 222.84
+ sex:fbs          1   197.86 223.86
+ fbs:exang        1   198.11 224.11
+ sex:exang        1   198.58 224.58
+ chol:fbs         1   198.60 224.60
<none>                200.60 224.60
+ sex:thal         1   198.63 224.63
+ fbs:slope        1   198.66 224.66
+ cp:chol          2   196.92 224.92
+ trestbps:exang   1   199.00 225.00
+ chol:slope       1   199.15 225.15
+ sex:trestbps     1   199.55 225.55
+ trestbps:chol    1   199.62 225.62
+ thalach:ca       1   199.72 225.72
+ exang:thal       1   199.87 225.87
+ chol:ca          1   199.88 225.88
+ exang:ca         1   199.99 225.99
+ fbs:thalach      1   200.09 226.09
+ chol:exang       1   200.10 226.10
+ cp:trestbps      2   198.14 226.14
+ sex:chol         1   200.15 226.15
+ fbs:ca           1   200.17 226.17
+ cp:ca            2   198.26 226.26
+ trestbps:thal    1   200.29 226.29
+ thalach:thal     1   200.32 226.32
+ slope:thal       1   200.37 226.37
+ sex:slope        1   200.38 226.38
+ trestbps:slope   1   200.39 226.39
+ sex:thalach      1   200.40 226.40
+ cp:thalach       2   198.42 226.42
+ trestbps:ca      1   200.47 226.47
+ trestbps:fbs     1   200.50 226.50
+ chol:thal        1   200.50 226.50
+ slope:ca         1   200.50 226.50
+ chol:thalach     1   200.52 226.52
+ ca:thal          1   200.52 226.52
+ sex:ca           1   200.53 226.53
+ thalach:exang    1   200.58 226.58
+ fbs:thal         1   200.59 226.59
+ trestbps:thalach 1   200.60 226.60
+ sex:cp           2   198.60 226.60
+ thalach:slope    1   200.60 226.60
+ cp:exang         2   198.87 226.87
```

```
+ cp:slope         2   200.07 228.07
+ cp:fbs           2   200.17 228.17
+ cp:thal          2   200.18 228.18

Step:  AIC=222.84
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope

                Df Deviance    AIC
+ sex:fbs         1   194.30 222.30
<none>                196.84 222.84
+ trestbps:exang    1   194.85 222.85
+ chol:fbs        1   195.11 223.11
+ fbs:exang       1   195.11 223.11
+ exang:ca        1   195.12 223.12
+ fbs:slope       1   195.16 223.16
+ cp:chol         2   193.34 223.34
+ chol:slope      1   195.46 223.46
+ sex:thal        1   195.50 223.50
+ sex:exang       1   195.63 223.63
+ trestbps:chol    1   195.94 223.94
+ chol:ca         1   196.01 224.01
+ sex:trestbps     1   196.02 224.02
+ exang:thal       1   196.08 224.08
+ chol:exang       1   196.13 224.13
+ thalach:exang    1   196.21 224.21
+ thalach:thal     1   196.28 224.28
+ thalach:ca       1   196.39 224.39
+ sex:chol         1   196.43 224.43
+ fbs:thalach      1   196.46 224.46
+ cp:thalach       2   194.52 224.52
+ trestbps:thal    1   196.54 224.54
+ cp:trestbps      2   194.54 224.54
+ fbs:ca           1   196.57 224.57
+ slope:ca         1   196.57 224.57
+ trestbps:slope   1   196.59 224.59
+ cp:ca            2   194.61 224.61
+ sex:slope        1   196.65 224.65
+ thalach:slope    1   196.68 224.68
+ sex:thalach      1   196.71 224.71
+ sex:ca           1   196.76 224.76
+ trestbps:ca      1   196.78 224.78
+ slope:thal       1   196.79 224.79
+ chol:thalach     1   196.79 224.79
+ cp:exang         2   194.80 224.80
+ trestbps:fbs     1   196.80 224.80
+ chol:thal        1   196.81 224.81
+ trestbps:thalach  1   196.83 224.83
+ ca:thal          1   196.83 224.83
+ fbs:thal         1   196.83 224.83
+ cp:slope         2   195.00 225.00
+ sex:cp           2   195.21 225.21
+ cp:fbs           2   196.17 226.17
+ cp:thal          2   196.45 226.45

Step:  AIC=222.3
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
```

```
   slope + ca + thal + exang:slope + sex:fbs

               Df Deviance    AIC
+ fbs:slope     1   190.88 220.88
+ trestbps:exang  1   191.97 221.97
<none>              194.30 222.30
+ exang:ca      1   192.39 222.39
+ fbs:exang     1   192.62 222.62
+ chol:ca       1   192.76 222.76
+ sex:thal      1   192.88 222.88
+ cp:chol       2   191.22 223.22
+ sex:exang     1   193.26 223.26
+ chol:slope    1   193.43 223.43
+ thalach:ca    1   193.56 223.56
+ sex:chol      1   193.57 223.57
+ sex:trestbps   1   193.59 223.59
+ trestbps:chol  1   193.60 223.60
+ chol:exang    1   193.60 223.60
+ exang:thal    1   193.65 223.65
+ thalach:exang  1   193.71 223.71
+ thalach:thal   1   193.77 223.77
+ sex:slope     1   193.84 223.84
+ cp:trestbps    2   191.87 223.87
+ trestbps:thal  1   193.88 223.88
+ sex:ca        1   193.91 223.91
+ fbs:ca        1   193.91 223.91
+ trestbps:slope  1   193.95 223.95
+ fbs:thal      1   193.98 223.98
+ cp:thalach     2   192.01 224.01
+ cp:slope       2   192.02 224.02
+ slope:ca       1   194.05 224.05
+ chol:thal      1   194.13 224.13
+ sex:thalach    1   194.14 224.14
+ chol:fbs       1   194.14 224.14
+ fbs:thalach    1   194.16 224.16
+ thalach:slope  1   194.17 224.17
+ trestbps:fbs   1   194.25 224.25
+ trestbps:thalach  1   194.28 224.28
+ chol:thalach   1   194.28 224.28
+ cp:exang       2   192.29 224.29
+ cp:ca          2   192.30 224.30
+ trestbps:ca    1   194.30 224.30
+ slope:thal     1   194.30 224.30
+ ca:thal        1   194.30 224.30
+ sex:cp         2   192.50 224.50
+ cp:fbs         2   193.92 225.92
+ cp:thal        2   194.01 226.01

Step:  AIC=220.88
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
   slope + ca + thal + exang:slope + sex:fbs + fbs:slope

               Df Deviance    AIC
+ exang:ca      1   187.51 219.51
<none>              190.88 220.88
+ fbs:exang     1   188.96 220.96
+ trestbps:exang  1   189.00 221.00
```

```
+ thalach:ca       1   189.28 221.28
+ sex:exang        1   189.49 221.49
+ sex:thal         1   189.50 221.50
+ chol:ca          1   189.65 221.65
+ cp:chol          2   187.78 221.78
+ sex:ca           1   189.80 221.80
+ chol:slope       1   189.81 221.81
+ cp:trestbps      2   187.82 221.82
+ sex:trestbps     1   189.92 221.92
+ sex:slope        1   189.98 221.98
+ cp:exang         2   188.09 222.09
+ sex:chol         1   190.16 222.16
+ exang:thal       1   190.17 222.17
+ fbs:ca           1   190.20 222.20
+ chol:exang       1   190.26 222.26
+ thalach:exang    1   190.26 222.26
+ trestbps:chol    1   190.27 222.27
+ thalach:thal     1   190.40 222.40
+ trestbps:thal    1   190.42 222.42
+ fbs:thal         1   190.50 222.50
+ trestbps:slope   1   190.68 222.68
+ trestbps:fbs     1   190.71 222.71
+ chol:thal        1   190.77 222.77
+ ca:thal          1   190.77 222.77
+ sex:thalach      1   190.77 222.77
+ chol:thalach     1   190.80 222.80
+ thalach:slope    1   190.81 222.81
+ chol:fbs         1   190.83 222.83
+ trestbps:ca      1   190.86 222.86
+ trestbps:thalach 1   190.86 222.86
+ fbs:thalach      1   190.87 222.87
+ slope:thal       1   190.87 222.87
+ slope:ca         1   190.88 222.88
+ cp:ca            2   189.06 223.06
+ cp:slope         2   189.07 223.07
+ cp:fbs           2   189.14 223.14
+ sex:cp           2   189.14 223.14
+ cp:thalach       2   189.35 223.35
+ cp:thal          2   190.69 224.69

Step:  AIC=219.51
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca

                Df Deviance    AIC
+ trestbps:exang    1   183.52 217.52
+ thalach:ca        1   185.36 219.36
<none>                  187.51 219.51
+ chol:ca           1   185.75 219.75
+ fbs:ca            1   185.97 219.97
+ sex:trestbps      1   186.07 220.07
+ sex:exang         1   186.10 220.10
+ chol:slope        1   186.18 220.18
+ sex:thal          1   186.22 220.22
+ thalach:exang     1   186.30 220.30
+ cp:trestbps       2   184.32 220.32
+ cp:chol           2   184.37 220.37
```

```
+ sex:ca           1   186.47 220.47
+ chol:exang       1   186.55 220.55
+ cp:exang         2   184.55 220.55
+ exang:thal       1   186.64 220.64
+ sex:slope        1   186.65 220.65
+ trestbps:chol    1   186.66 220.66
+ sex:chol         1   186.80 220.80
+ trestbps:thal    1   186.85 220.85
+ fbs:exang        1   186.97 220.97
+ thalach:thal     1   187.19 221.19
+ trestbps:fbs     1   187.29 221.29
+ fbs:thal         1   187.33 221.33
+ cp:slope         2   185.35 221.35
+ trestbps:slope   1   187.39 221.39
+ chol:thal        1   187.40 221.40
+ chol:thalach     1   187.43 221.43
+ sex:thalach      1   187.44 221.44
+ thalach:slope    1   187.46 221.46
+ trestbps:thalach 1   187.47 221.47
+ slope:ca         1   187.47 221.47
+ trestbps:ca      1   187.47 221.47
+ slope:thal       1   187.49 221.49
+ fbs:thalach      1   187.49 221.49
+ chol:fbs         1   187.50 221.50
+ ca:thal          1   187.51 221.51
+ sex:cp           2   185.54 221.54
+ cp:thalach       2   185.99 221.99
+ cp:fbs           2   186.33 222.33
+ cp:ca            2   186.35 222.35
+ cp:thal          2   187.19 223.19

Step:  AIC=217.52
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang

                Df Deviance    AIC
+ thalach:ca       1   181.17 217.17
+ fbs:ca           1   181.25 217.25
<none>                 183.52 217.52
+ chol:slope       1   181.59 217.59
+ exang:thal       1   181.70 217.70
+ sex:thal         1   182.05 218.05
+ cp:chol          2   180.13 218.13
+ thalach:exang    1   182.18 218.18
+ chol:ca          1   182.30 218.30
+ trestbps:chol    1   182.69 218.69
+ sex:trestbps     1   182.95 218.95
+ sex:chol         1   182.96 218.96
+ sex:slope        1   183.02 219.02
+ cp:exang         2   181.05 219.05
+ sex:ca           1   183.06 219.06
+ trestbps:fbs     1   183.07 219.07
+ thalach:thal     1   183.19 219.19
+ trestbps:thal    1   183.28 219.28
+ sex:exang        1   183.32 219.32
+ sex:thalach      1   183.33 219.33
```

```
+ fbs:thal         1   183.36 219.36
+ trestbps:thalach  1   183.37 219.37
+ chol:exang       1   183.41 219.41
+ chol:thal        1   183.43 219.43
+ trestbps:ca      1   183.45 219.45
+ fbs:exang        1   183.48 219.48
+ fbs:thalach      1   183.49 219.49
+ slope:ca         1   183.50 219.50
+ chol:fbs         1   183.51 219.51
+ chol:thalach     1   183.51 219.51
+ slope:thal       1   183.51 219.51
+ trestbps:slope   1   183.51 219.51
+ thalach:slope    1   183.51 219.51
+ ca:thal          1   183.52 219.52
+ cp:slope         2   181.54 219.54
+ cp:ca            2   181.81 219.81
+ cp:thalach       2   182.04 220.04
+ cp:fbs           2   182.12 220.12
+ sex:cp           2   182.14 220.14
+ cp:trestbps      2   182.23 220.23
+ cp:thal          2   183.07 221.07

Step:  AIC=217.17
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang + thalach:ca

                Df Deviance    AIC
+ fbs:ca          1   178.60 216.60
+ thalach:exang   1   178.78 216.78
<none>                181.17 217.17
+ sex:thal        1   179.18 217.18
+ cp:chol         2   177.32 217.32
+ chol:slope      1   179.45 217.45
+ chol:ca         1   179.58 217.58
+ exang:thal      1   179.75 217.75
+ trestbps:chol   1   180.47 218.47
+ sex:slope       1   180.53 218.53
+ sex:trestbps    1   180.60 218.60
+ sex:chol        1   180.76 218.76
+ fbs:thal        1   180.78 218.78
+ cp:slope        2   178.80 218.80
+ cp:thalach      2   178.81 218.81
+ sex:ca          1   180.82 218.82
+ trestbps:fbs    1   180.86 218.86
+ thalach:thal    1   180.87 218.87
+ sex:exang       1   180.90 218.90
+ cp:exang        2   178.91 218.91
+ trestbps:thal   1   181.00 219.00
+ chol:exang      1   181.02 219.02
+ chol:thal       1   181.07 219.07
+ slope:ca        1   181.09 219.09
+ chol:thalach    1   181.15 219.15
+ thalach:slope   1   181.15 219.15
+ trestbps:slope  1   181.15 219.15
+ sex:thalach     1   181.15 219.15
+ trestbps:thalach  1   181.15 219.15
```

```
+ ca:thal          1   181.16 219.16
+ fbs:exang        1   181.16 219.16
+ trestbps:ca      1   181.17 219.17
+ fbs:thalach      1   181.17 219.17
+ slope:thal       1   181.17 219.17
+ chol:fbs         1   181.17 219.17
+ cp:fbs           2   179.37 219.37
+ cp:trestbps      2   179.45 219.45
+ sex:cp           2   179.90 219.90
+ cp:ca            2   179.97 219.97
+ cp:thal          2   180.85 220.85

Step:  AIC=216.6
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang + thalach:ca + fbs:ca

                Df Deviance    AIC
+ thalach:exang     1   176.14 216.14
<none>                  178.60 216.60
+ sex:thal          1   176.67 216.67
+ exang:thal        1   176.80 216.80
+ fbs:exang         1   176.89 216.89
+ chol:ca           1   176.90 216.90
+ cp:chol           2   174.92 216.92
+ chol:slope        1   177.03 217.03
+ fbs:thal          1   177.52 217.52
+ trestbps:chol     1   177.71 217.71
+ cp:thalach        2   175.77 217.77
+ sex:slope         1   178.07 218.07
+ sex:chol          1   178.09 218.09
+ thalach:thal      1   178.10 218.10
+ sex:trestbps      1   178.18 218.18
+ cp:slope          2   176.23 218.23
+ trestbps:fbs      1   178.24 218.24
+ chol:thal         1   178.45 218.45
+ trestbps:thalach  1   178.48 218.48
+ chol:exang        1   178.48 218.48
+ sex:ca            1   178.51 218.51
+ fbs:thalach       1   178.51 218.51
+ cp:exang          2   176.54 218.54
+ trestbps:thal     1   178.56 218.56
+ sex:exang         1   178.56 218.56
+ slope:ca          1   178.57 218.57
+ chol:fbs          1   178.58 218.58
+ thalach:slope     1   178.58 218.58
+ slope:thal        1   178.59 218.59
+ trestbps:slope    1   178.59 218.59
+ trestbps:ca       1   178.59 218.59
+ ca:thal           1   178.60 218.60
+ chol:thalach      1   178.60 218.60
+ sex:thalach       1   178.60 218.60
+ cp:fbs            2   176.75 218.75
+ cp:trestbps       2   176.86 218.86
+ cp:ca             2   177.46 219.46
+ sex:cp            2   177.54 219.54
+ cp:thal           2   178.18 220.18
```

```
Step:  AIC=216.14
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang + thalach:ca + fbs:ca + thalach:exang

                Df Deviance    AIC
+ sex:thal       1   174.11 216.11
<none>               176.14 216.14
+ exang:thal     1   174.16 216.16
+ chol:ca        1   174.31 216.31
+ chol:slope     1   174.68 216.68
+ cp:chol        2   172.68 216.68
+ fbs:exang      1   174.79 216.79
+ fbs:thal       1   174.90 216.90
+ cp:exang       2   173.13 217.13
+ trestbps:chol  1   175.13 217.13
+ trestbps:fbs   1   175.51 217.51
+ sex:trestbps   1   175.72 217.72
+ sex:chol       1   175.75 217.75
+ sex:slope      1   175.75 217.75
+ cp:slope       2   173.89 217.89
+ chol:fbs       1   175.95 217.95
+ thalach:slope  1   175.95 217.95
+ cp:trestbps    2   174.00 218.00
+ chol:thal      1   176.00 218.00
+ slope:thal     1   176.07 218.07
+ thalach:thal   1   176.07 218.07
+ trestbps:thalach 1   176.07 218.07
+ fbs:thalach    1   176.09 218.09
+ sex:ca         1   176.10 218.10
+ chol:exang     1   176.10 218.10
+ ca:thal        1   176.10 218.10
+ sex:thalach    1   176.11 218.11
+ slope:ca       1   176.12 218.12
+ chol:thalach   1   176.13 218.13
+ sex:exang      1   176.13 218.13
+ trestbps:ca    1   176.13 218.13
+ trestbps:thal  1   176.14 218.14
+ cp:fbs         2   174.14 218.14
+ trestbps:slope 1   176.14 218.14
+ cp:thalach     2   174.21 218.21
+ cp:ca          2   174.97 218.97
+ sex:cp         2   175.15 219.15
+ cp:thal        2   175.34 219.34

Step:  AIC=216.11
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang + thalach:ca + fbs:ca + thalach:exang + sex:thal

                Df Deviance    AIC
+ cp:chol        2   168.60 214.60
+ chol:slope     1   171.72 215.72
<none>               174.11 216.11
+ exang:thal     1   172.25 216.25
+ fbs:thal       1   172.32 216.32
```

```
+ trestbps:chol     1   172.33 216.33
+ chol:ca           1   172.78 216.78
+ fbs:exang         1   172.84 216.84
+ sex:cp            2   170.92 216.92
+ sex:chol          1   173.22 217.22
+ trestbps:fbs      1   173.40 217.40
+ cp:exang          2   171.51 217.51
+ sex:thalach       1   173.53 217.53
+ sex:trestbps      1   173.62 217.62
+ thalach:thal      1   173.70 217.70
+ cp:fbs            2   171.72 217.72
+ cp:slope          2   171.81 217.81
+ thalach:slope     1   173.85 217.85
+ chol:fbs          1   173.87 217.87
+ trestbps:thalach  1   173.92 217.92
+ trestbps:ca       1   173.97 217.97
+ ca:thal           1   174.00 218.00
+ sex:slope         1   174.03 218.03
+ trestbps:thal     1   174.05 218.05
+ sex:ca            1   174.07 218.07
+ chol:exang        1   174.08 218.08
+ chol:thal         1   174.10 218.10
+ cp:trestbps       2   172.10 218.10
+ fbs:thalach       1   174.11 218.11
+ chol:thalach      1   174.11 218.11
+ sex:exang         1   174.11 218.11
+ slope:ca          1   174.11 218.11
+ trestbps:slope    1   174.11 218.11
+ slope:thal        1   174.11 218.11
+ cp:thalach        2   172.91 218.91
+ cp:ca             2   173.04 219.04
+ cp:thal           2   173.45 219.45

Step:  AIC=214.6
target ~ sex + cp + trestbps + chol + fbs + thalach + exang +
    slope + ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
    trestbps:exang + thalach:ca + fbs:ca + thalach:exang + sex:thal +
    cp:chol

                Df Deviance    AIC
<none>               168.60 214.60
+ fbs:thal         1   166.91 214.91
+ exang:thal       1   167.00 215.00
+ chol:slope       1   167.10 215.10
+ chol:ca          1   167.13 215.13
+ sex:thalach      1   167.24 215.24
+ fbs:exang        1   167.35 215.35
+ cp:slope         2   165.47 215.47
+ thalach:thal     1   167.90 215.90
+ trestbps:chol    1   167.94 215.94
+ ca:thal          1   168.15 216.15
+ cp:fbs           2   166.19 216.19
+ trestbps:fbs     1   168.25 216.25
+ cp:trestbps      2   166.37 216.37
+ sex:exang        1   168.42 216.42
+ trestbps:thal    1   168.44 216.44
+ thalach:slope    1   168.44 216.44
```

```
+ trestbps:ca       1   168.44 216.44
+ chol:fbs          1   168.47 216.47
+ sex:ca            1   168.47 216.47
+ sex:cp            2   166.47 216.47
+ sex:slope         1   168.51 216.51
+ cp:exang          2   166.53 216.53
+ sex:trestbps      1   168.54 216.54
+ sex:chol          1   168.56 216.56
+ slope:thal        1   168.56 216.56
+ chol:thal         1   168.56 216.56
+ trestbps:thalach  1   168.57 216.57
+ fbs:thalach       1   168.58 216.58
+ trestbps:slope    1   168.59 216.59
+ chol:exang        1   168.59 216.59
+ chol:thalach      1   168.60 216.60
+ slope:ca          1   168.60 216.60
+ cp:ca             2   166.91 216.91
+ cp:thal           2   167.97 217.97
+ cp:thalach        2   168.10 218.10
```

model 2

```
> summary(select.2)

Call:
glm(formula = target ~ sex + cp + trestbps + chol + fbs + thalach +
    exang + slope + ca + thal + exang:slope + sex:fbs + fbs:slope +
    exang:ca + trestbps:exang + thalach:ca + fbs:ca + thalach:exang +
    sex:thal + cp:chol, family = "binomial", data = heart1)

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-3.2694  -0.4296  -0.0565   0.2711   2.5510

Coefficients:
                  Estimate Std. Error z value Pr(>|z|)
(Intercept)       -0.748855   4.044172  -0.185  0.85310
sexM              -0.422105   1.575812  -0.268  0.78880
cpasymptomatic     4.231470   3.237593   1.307  0.19122
cpnon_anginal      6.775567   3.399967   1.993  0.04628 *
trestbps           0.005113   0.013687   0.374  0.70874
chol               0.020434   0.010570   1.933  0.05321 .
fbsTrue            6.101057   2.596119   2.350  0.01877 *
thalach           -0.031219   0.015716  -1.986  0.04699 *
exangYes          -12.229935   5.061918  -2.416  0.01569 *
slopeup            -0.789815   0.532386  -1.484  0.13793
ca                -3.955055   2.069777  -1.911  0.05602 .
thalnormal        -4.219209   1.669240  -2.528  0.01148 *
exangYes:slopeup  -2.839590   1.144702  -2.481  0.01311 *
sexM:fbsTrue      -7.982742   2.772779  -2.879  0.00399 **
fbsTrue:slopeup   -8.435324   3.451059  -2.444  0.01451 *
exangYes:ca        2.928729   1.096162   2.672  0.00754 **
trestbps:exangYes  0.064587   0.027683   2.333  0.01964 *
thalach:ca         0.034936   0.014104   2.477  0.01325 *
fbsTrue:ca         1.886769   1.291571   1.461  0.14406
thalach:exangYes   0.035525   0.024176   1.469  0.14172
```

```
sexM:thalnormal      3.067549   1.712458   1.791  0.07324 .
cpasymptomatic:chol  -0.010954   0.012892  -0.850  0.39550
cpnon_anginal:chol   -0.028377   0.013742  -2.065  0.03893 *
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 409.95  on 296  degrees of freedom
Residual deviance: 168.60  on 274  degrees of freedom
AIC: 214.6

Number of Fisher Scoring iterations: 8

> coef(select.2)
      (Intercept)             sexM      cpasymptomatic       cpnon_anginal            trestbps                chol
     -0.748855160       -0.422105336        4.231470256        6.775567135        0.005112785        0.020433762
          fbsTrue            thalach          exangYes           slopeup                ca          thalnormal
      6.101057188       -0.031218683      -12.229934801       -0.789814583       -3.955054944       -4.219209069
  exangYes:slopeup      sexM:fbsTrue     fbsTrue:slopeup      exangYes:ca   trestbps:exangYes         thalach:ca
     -2.839589972       -7.982741976       -8.435324047        2.928728815        0.064587296        0.034936465
       fbsTrue:ca     thalach:exangYes     sexM:thalnormal cpasymptomatic:chol   cpnon_anginal:chol
      1.886769110        0.035524638        3.067549209       -0.010953740       -0.028376734
```

Anova test of model 2

```
> library(car)# Anova
> Anova(select.2) #based on this, exang not significant remove exang in fit.4
Analysis of Deviance Table (Type II tests)
```

Anova table

```
Response: target
             LR Chisq Df Pr(>Chisq)
sex            10.938  1  0.0009422 ***
cp             13.282  2  0.0013060 **
trestbps        4.592  1  0.0321253 *
chol            0.971  1  0.3243812
fbs             4.987  1  0.0255352 *
thalach         0.546  1  0.4598773
exang           4.806  1  0.0283614 *
slope          14.386  1  0.0001489 ***
ca             37.765  1  7.979e-10 ***
thal           10.674  1  0.0010867 **
exang:slope     6.779  1  0.0092261 **
sex:fbs         9.403  1  0.0021666 **
fbs:slope      10.029  1  0.0015413 **
exang:ca       10.005  1  0.0015608 **
trestbps:exang  6.184  1  0.0128931 *
thalach:ca      5.871  1  0.0153966 *
fbs:ca          2.729  1  0.0985694 .
thalach:exang   2.180  1  0.1398572
sex:thal        4.079  1  0.0434178 *
```

```
cp:chol          5.510  2  0.0635985 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

final model

```
> fit.final=glm(target ~ sex + cp + trestbps  + fbs  + exang + slope + ca + thal + exang:slope + sex:fbs + fbs:slope
+
+              exang:ca + trestbps:exang  + fbs:ca + sex:thal,
+              data=heart1, family=binomial)
> summary(fit.final)

Call:
glm(formula = target ~ sex + cp + trestbps + fbs + exang + slope +
   ca + thal + exang:slope + sex:fbs + fbs:slope + exang:ca +
   trestbps:exang + fbs:ca + sex:thal, family = binomial, data = heart1)

Deviance Residuals:
   Min      1Q  Median      3Q     Max
-3.4569  -0.4336  -0.0947   0.2612   2.4811

Coefficients:
              Estimate Std. Error z value Pr(>|z|)
(Intercept)     -1.95595    2.13466  -0.916  0.35952
sexM             0.14207    1.17904   0.121  0.90409
cpasymptomatic    1.43154    0.49096   2.916  0.00355 **
cpnon_anginal    -0.14392    0.53785  -0.268  0.78901
trestbps         0.01199    0.01292   0.928  0.35343
fbsTrue          6.10370    2.41927   2.523  0.01164 *
exangYes        -6.48437    3.53362  -1.835  0.06650 .
slopeup         -0.84664    0.47333  -1.789  0.07366 .
ca               1.25061    0.30519   4.098 4.17e-05 ***
thalnormal      -3.21868    1.24334  -2.589  0.00963 **
exangYes:slopeup  -2.33809    1.03681  -2.255  0.02413 *
sexM:fbsTrue     -7.79417    2.59945  -2.998  0.00271 **
fbsTrue:slopeup   -7.29079    3.34994  -2.176  0.02953 *
exangYes:ca       2.43431    1.05663   2.304  0.02123 *
trestbps:exangYes  0.05952    0.02731   2.179  0.02931 *
fbsTrue:ca        1.79628    1.29162   1.391  0.16431
sexM:thalnormal    2.01785    1.32224   1.526  0.12699
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

   Null deviance: 409.95  on 296  degrees of freedom
Residual deviance: 181.36  on 280  degrees of freedom
AIC: 215.36

Number of Fisher Scoring iterations: 8

> coef(fit.final)
     (Intercept)            sexM    cpasymptomatic     cpnon_anginal         trestbps          fbsTrue
     -1.95594655       0.14207425       1.43154201       -0.14392298       0.01199279       6.10370348
       exangYes          slopeup             ca       thalnormal  exangYes:slopeup      sexM:fbsTrue
```

```
    -6.48437093      -0.84664308       1.25061443      -3.21867936      -2.33808641      -7.79417495
 fbsTrue:slopeup      exangYes:ca trestbps:exangYes       fbsTrue:ca   sexM:thalnormal
    -7.29079329       2.43430601       0.05952450       1.79627544       2.01784581
> confint(fit.final) #likelihood ratio CI
Waiting for profiling to be done...
                        2.5 %      97.5 %
(Intercept)       -6.226246301  2.22132173
sexM              -2.308944600  2.38077245
cpasymptomatic     0.491543888  2.42788816
cpnon_anginal     -1.215875696  0.90940084
trestbps          -0.013093513  0.03802441
fbsTrue            1.413968216 11.12328113
exangYes          -13.828832009  0.13770603
slopeup           -1.793345893  0.07425921
ca                0.686246497  1.89046044
thalnormal        -5.832627281 -0.91695987
exangYes:slopeup   -4.513718453 -0.40889522
sexM:fbsTrue      -13.280754706 -2.86420426
fbsTrue:slopeup   -14.570415005 -1.56275404
exangYes:ca        0.593558905  4.72522190
trestbps:exangYes   0.008979013  0.11683091
fbsTrue:ca        -0.442775296  4.57517758
sexM:thalnormal    -0.441355023  4.77877217
> Anova(fit.final)
Analysis of Deviance Table (Type II tests)

Response: target
            LR Chisq Df Pr(>Chisq)
sex             7.956  1   0.004792 **
cp             13.378  2   0.001245 **
trestbps        7.105  1   0.007688 **
fbs             3.854  1   0.049623 *
exang           4.702  1   0.030134 *
slope          17.300  1  3.191e-05 ***
ca             43.574  1  4.082e-11 ***
thal           12.267  1   0.000461 ***
exang:slope     5.745  1   0.016536 *
sex:fbs         9.482  1   0.002075 **
fbs:slope       7.251  1   0.007086 **
exang:ca        7.391  1   0.006556 **
trestbps:exang    5.421  1   0.019894 *
fbs:ca          2.316  1   0.128061
sex:thal        2.540  1   0.111023
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
>
>
> oddsratio=cbind(coef(fit.final),confint(fit.final),exp(coef(fit.final)))
Waiting for profiling to be done...
> colnames(oddsratio)=c("coefficient","95%CI(2.5%)","95%CI(97.5.5%)","odds ratio")
> oddsratio=format(round(oddsratio,2), nsmall=2)
```

odds ratio

```
> oddsratio
             coefficient 95%CI(2.5%) 95%CI(97.5.5%) odds ratio
```

```
(Intercept)      " -1.96"   " -6.23"   "  2.22"      "  0.14"
sexM            "  0.14"   " -2.31"   "  2.38"      "  1.15"
cpasymptomatic   "  1.43"   "  0.49"   "  2.43"      "  4.19"
cpnon_anginal    " -0.14"   " -1.22"   "  0.91"      "  0.87"
trestbps         "  0.01"   " -0.01"   "  0.04"      "  1.01"
fbsTrue          "  6.10"   "  1.41"   " 11.12"      "447.51"
exangYes         " -6.48"   "-13.83"   "  0.14"      "  0.00"
slopeup          " -0.85"   " -1.79"   "  0.07"      "  0.43"
ca              "  1.25"   "  0.69"   "  1.89"      "  3.49"
thalnormal       " -3.22"   " -5.83"   " -0.92"      "  0.04"
exangYes:slopeup  " -2.34"   " -4.51"   " -0.41"      "  0.10"
sexM:fbsTrue      " -7.79"   "-13.28"   " -2.86"      "  0.00"
fbsTrue:slopeup   " -7.29"   "-14.57"   " -1.56"      "  0.00"
exangYes:ca       "  2.43"   "  0.59"   "  4.73"      " 11.41"
trestbps:exangYes "  0.06"   "  0.01"   "  0.12"      "  1.06"
fbsTrue:ca        "  1.80"   " -0.44"   "  4.58"      "  6.03"
sexM:thalnormal   "  2.02"   " -0.44"   "  4.78"      "  7.52"
```

ROC curve

```
> #step 5. model evalution: sensitivity/specificity/ROC/AUC
> pi0=seq(1,0, length.out = 100)
> nsample=nrow(heart1)
> roc=NULL
> cv.set.list=split(sample(nsample),rep(1:10,length=nsample))  #10-fold cross-validation method
> for(k in 1:length(pi0))
+ {n_11=n_10=n_01=n_00=0
+ nsample=nrow(heart1)
+ for(i in 1:length(cv.set.list))
+ {
+   training=heart1[-cv.set.list[[i]],]
+   test=heart1[cv.set.list[[i]],]
+   fit.training=glm(target ~ sex + cp + trestbps  + fbs  + exang + slope + ca + thal + exang:slope + sex:fbs +
fbs:slope +
+                    exang:ca + trestbps:exang  + fbs:ca + sex:thal, data=training, family="binomial")
+   for(j in 1:length(cv.set.list[[i]]))
+   {if(predict(fit.training, test[j,], type="response")>=pi0[k])
+   {Y.pred.1=1}else{Y.pred.1=0}
+     if((test$target[j]==1)&(Y.pred.1==1))
+     {n_11=n_11+1}
+     if((test$target[j]==1)&(Y.pred.1==0))
+     {n_10=n_10+1}
+     if((test$target[j]==0)&(Y.pred.1==1))
+     {n_01=n_01+1}
+     if((test$target[j]==0)&(Y.pred.1==0))
+     {n_00=n_00+1}
+   }
+ }
+ sen=n_11/(n_10+n_11)
+ spe=n_00/(n_00+n_01)
+ roc=rbind(roc, c(1-spe, sen))
+ }
> plot(roc, type="s",xlim=c(0,1), ylim=c(0,1), col="red", main="ROC curve", xlab="1-Specificity",
ylab="Sensitivity")
> auc=sum(roc[-100, 2]*(roc[-1,1]-roc[-100,1]))
```

```
> auc #AUC area under ROC curve
[1] 0.9091697
> pred.accuracy=roc[,2]*sum(heart1$target==1)/nsample+(1-roc[,1])*sum(heart1$target==0)/nsample
> z.1=which.max(pred.accuracy)
> pi0[z.1] #best cut-off points
[1] 0.4949495
> pred.accuracy[z.1]  #best prediction accuracy
[1] 0.8518519
>
```