Predicting cancer diagnosis from cell imaging data

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4/7/2022

Abstract

This report investigates tumor diagnosis (malignant or benign) as a function of various cell nuclei measurements from a fine needle aspirate image of a breast tumor mass. The measurements include average cell nuclei radius, texture, perimeter, area, smoothness, compactness, concavity, concave points, symmetry, and fractal dimension. The primary goal of the report is to fit a multiple logistic regression model using the aforementioned predictors that can predict tumor diagnosis with reasonable accuracy and precision. Additionally, we would like to determine which predictors are most predictive of tumor diagnosis. From our best model, which only included a subset of the predictors, we found that mean texture, smoothness, square root concavity, log compactness, and log area are all significant predictors of tumor diagnosis. We found five significant interactions between these five predictor variables. Altogether, 96.2% of malignant cases and 96.9% of benign cases were correctly predicted by our final model.

Introduction

Each year, approximately 250,000 people are diagnosed with breast cancer in the United States alone. To treat these patients, the US spends upwards of 20 billion dollars each year. Early detection of cancer through the assessment of tumors as benign or malignant is essential to limiting morbidities and health care costs associated with breast cancer. Obtaining an accurate assessment of tumor diagnosis is of great importance to doctors, patients, and their families. One method of tumor diagnosis is by analyzing cell features and measurements obtained by a fine needle aspirate (FNA) biopsy procedure. The images generated by the FNA are analyzed by a cytotechnologist or pathologist for signs of malignancy. Importantly, multiple logistic regression models could be valuable resources that expedite the process and help inform the doctors making the final diagnosis.

This report examines data from 569 breast tumor samples from patients in Wisconsin. In addition to our response variable (diagnosis), there are various cell nuclei measurements commonly calculated by computers from FNA images. The predictor variables included in our report are:

a) mean radius (mean of distances from center to points on the perimeter)
b) mean texture (standard deviation of gray-scale values)
c) mean perimeter
d) mean area
e) mean smoothness (local variation in radius lengths)
f) mean compactness (perimeter^2 / area - 1)
g) mean concavity (severity of concave portions of the contour)
h) mean concave points (number of concave portions of the contour)
i) mean symmetry
j) mean fractal dimension ("coastline approximation" - 1)

All predictor variables are quantitative.

The primary goal of this report is to determine what cell nuclei measurements are most predictive of tumor

diagnosis. Additionally, we want to assess how effective a combination of cell nuclei measurements can be at predicting tumor diagnosis.

Loading the data

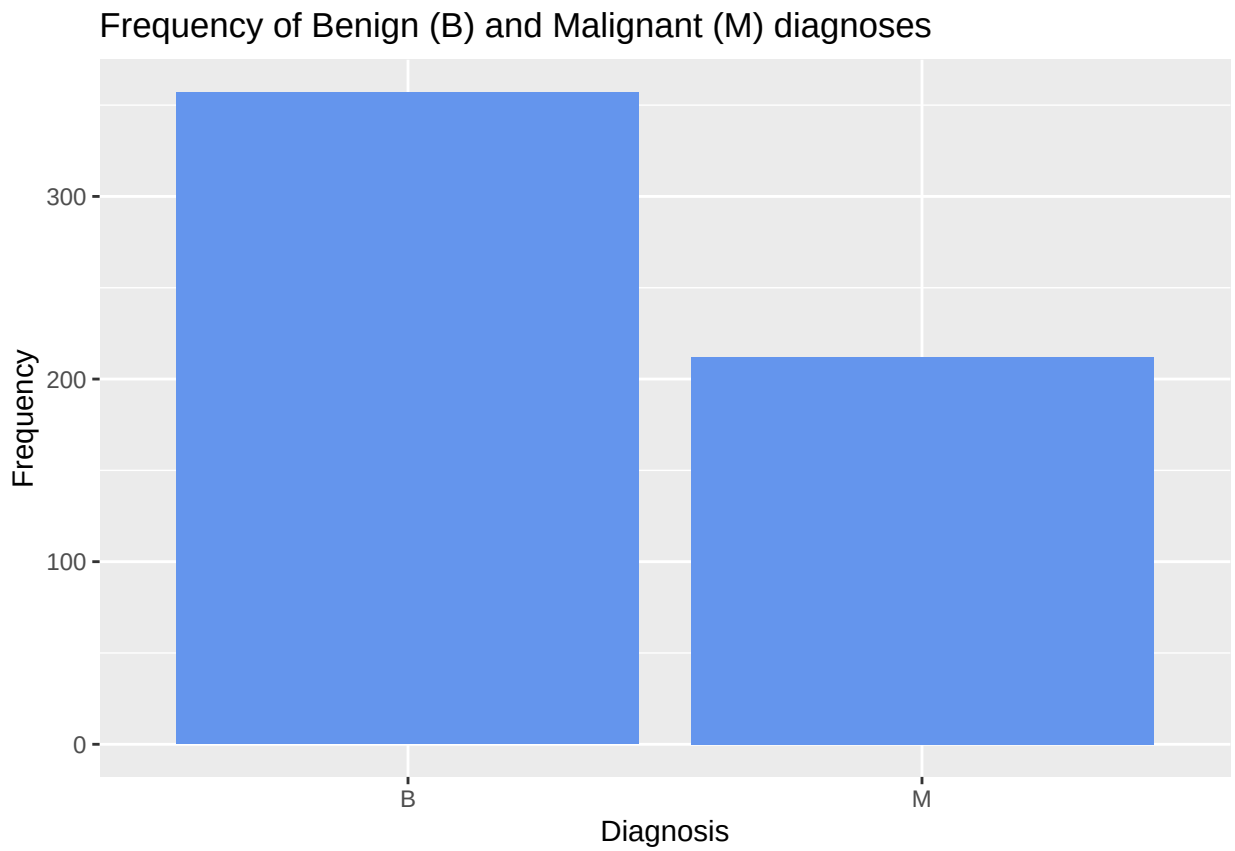
```
library(readxl)
wisconsin <- read_excel("G:/Shared drives/math 327 project/wisconsin_cancer.xlsx")
#wisconsin <- read_excel("/Users/nathananderson/Downloads/wisconsin_cancer.xlsx")
wisconsin$diagnosis <- as.factor(wisconsin$diagnosis)
wisconsin <- wisconsin[2:12]
diagnosis = wisconsin$diagnosis
radius_mean = wisconsin$radius_mean
texture_mean = wisconsin$texture_mean
perimeter_mean = wisconsin$perimeter_mean
area_mean = wisconsin$area_mean
smoothness_mean = wisconsin$smoothness_mean
compactness_mean = wisconsin$compactness_mean
concavity_mean = wisconsin$concavity_mean
concave_points_mean = wisconsin$`concave points_mean`
symmetry_mean = wisconsin$symmetry_mean
fractal_dimension_mean = wisconsin$fractal_dimension_mean
```

Data Characteristics

```
#Response variable characteristics
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.0.5
```

```
ggplot(wisconsin, aes(x = diagnosis)) + geom_bar(fill="cornflowerblue") + labs(x = "Diagnosis", y = "Fr
                                                                              title = "Frequency of Benign (B) and Malignan
```




```
summary(wisconsin$diagnosis)
```

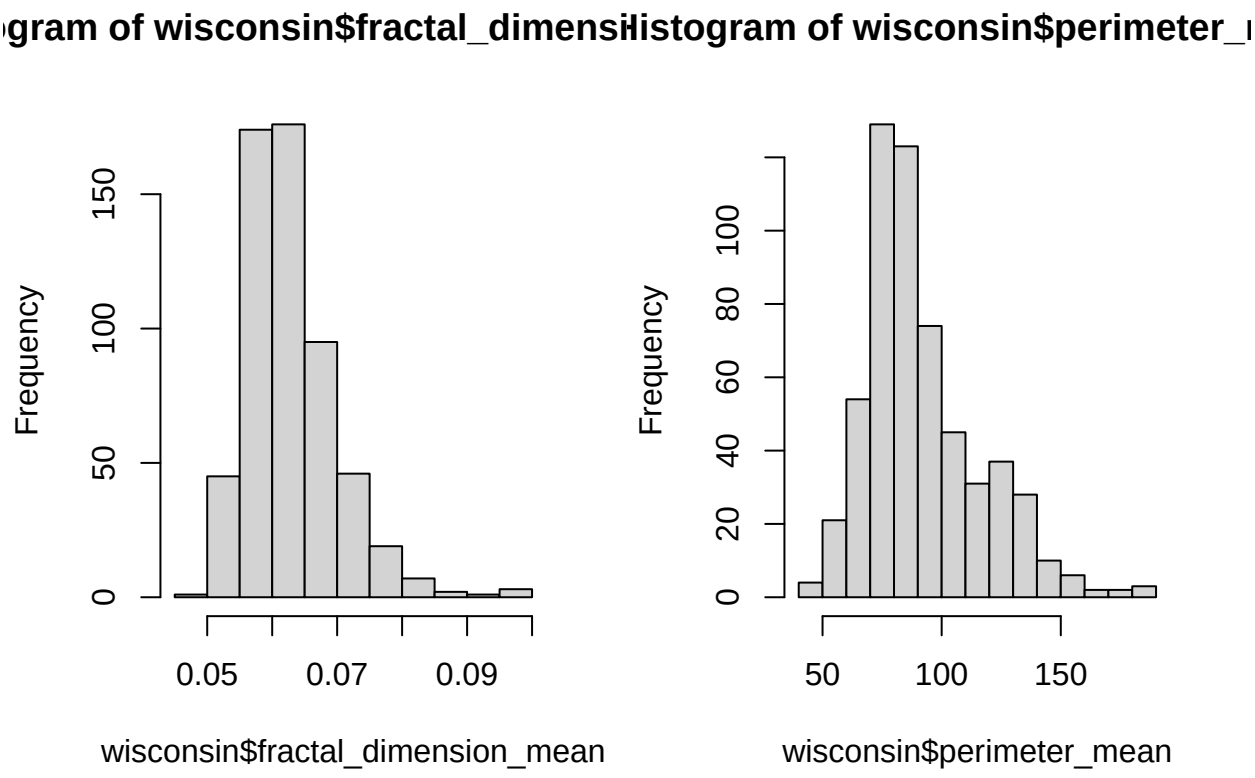
```
##   B   M
## 357 212
```

Our response variable, diagnosis, shows that 357 patient tumors were classified as benign and 212 patient tumors were classified as malignant. Our overall sample size is 569.

Predictor variable distributions

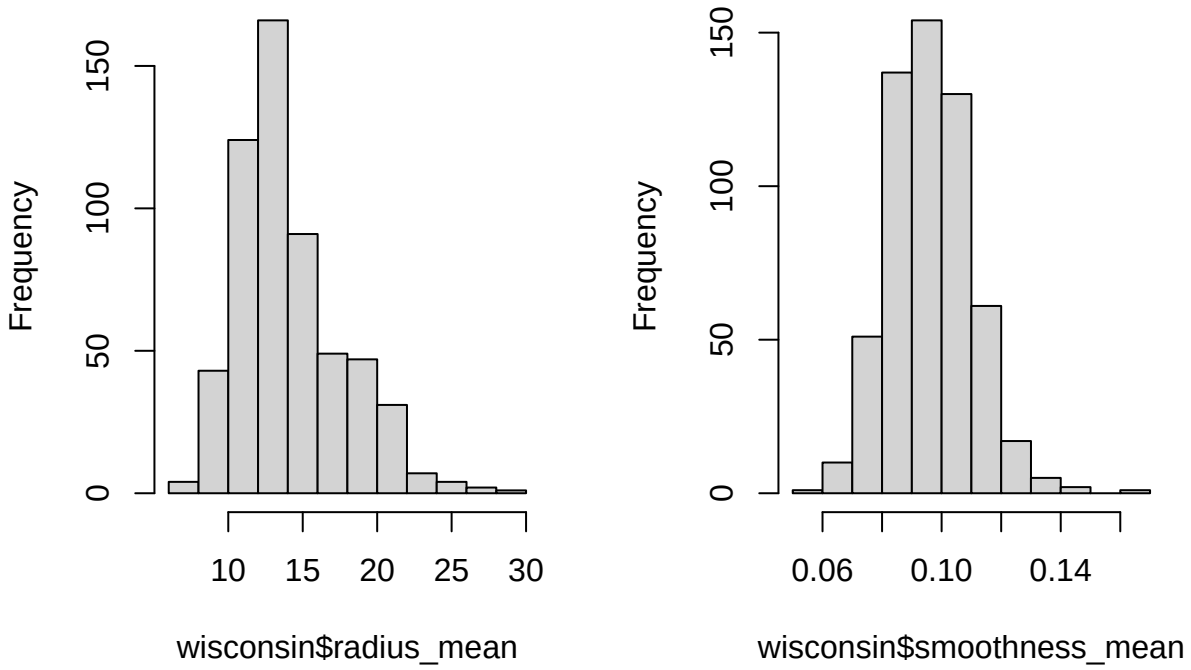
```
par(mfrow = c(1, 2))
hist(wisconsin$fractal_dimension_mean)

hist(wisconsin$perimeter_mean)
```



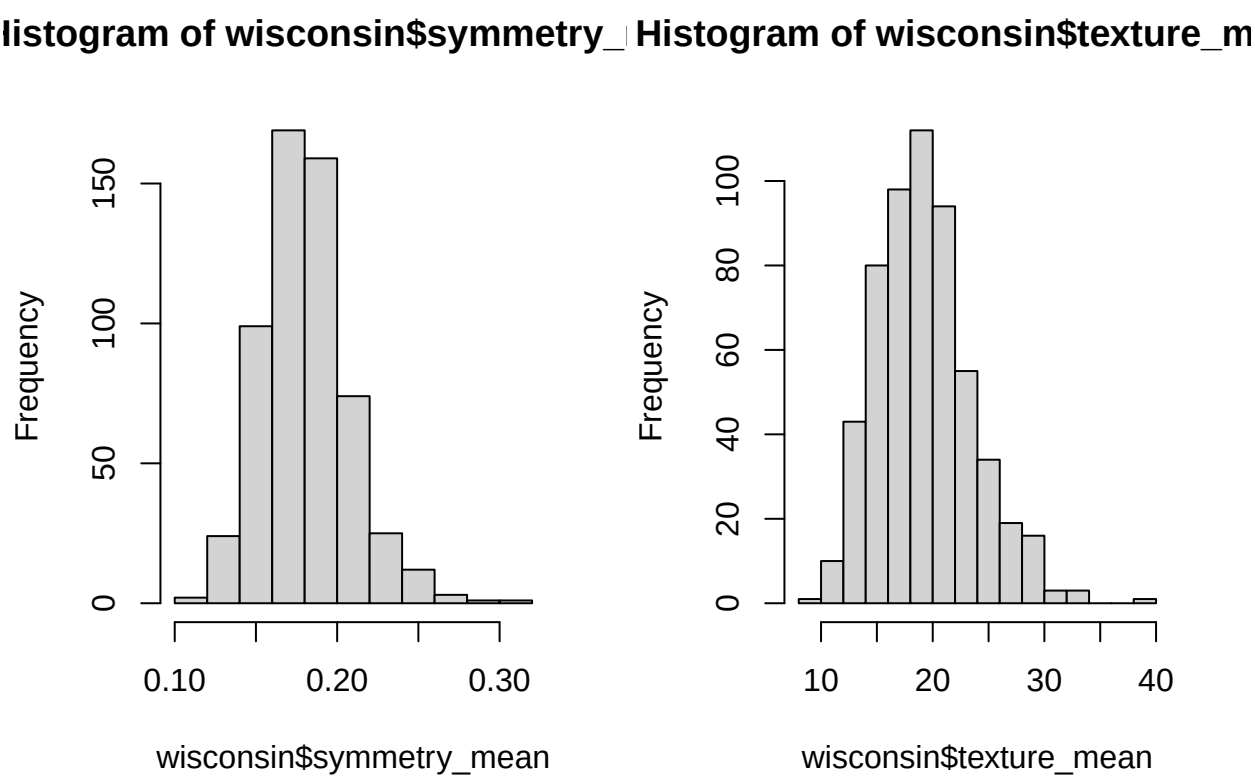

```
hist(wisconsin$radius_mean)

hist(wisconsin$smoothness_mean)
```



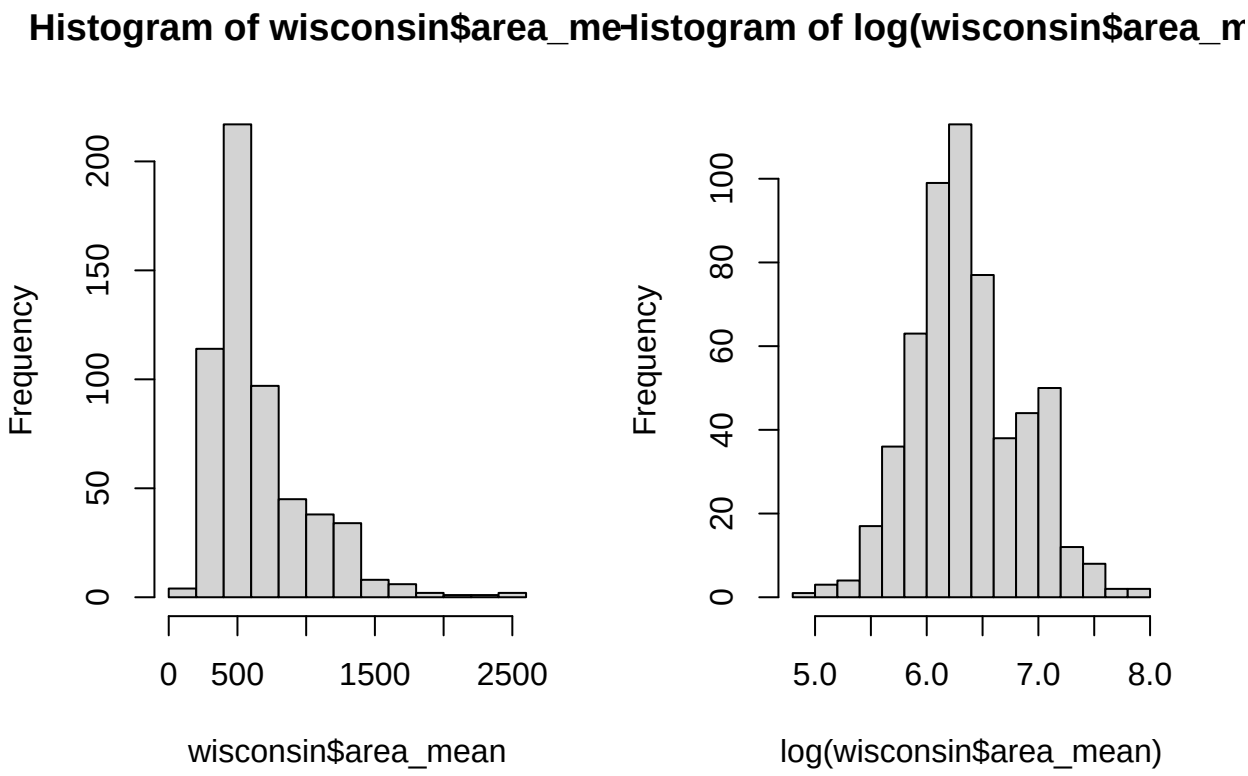

```
hist(wisconsin$symmetry_mean)

hist(wisconsin$texture_mean)
```



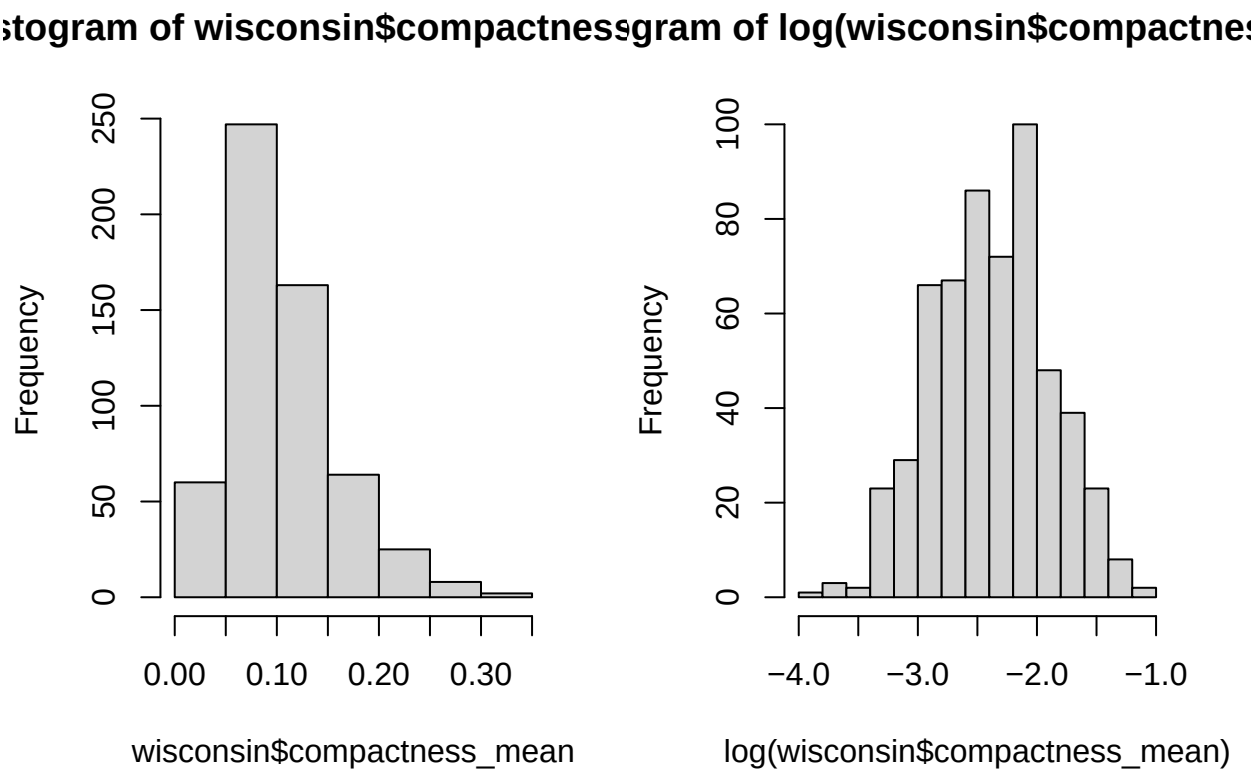
Mean fractal dimension, perimeter, radius, smoothness, symmetry, and texture are all approximately normally distributed or only mildly right skewed. As a result, we will not be transforming these predictor variables.

```
par(mfrow = c(1,2))
hist(wisconsin$area_mean)
hist(log(wisconsin$area_mean))
```



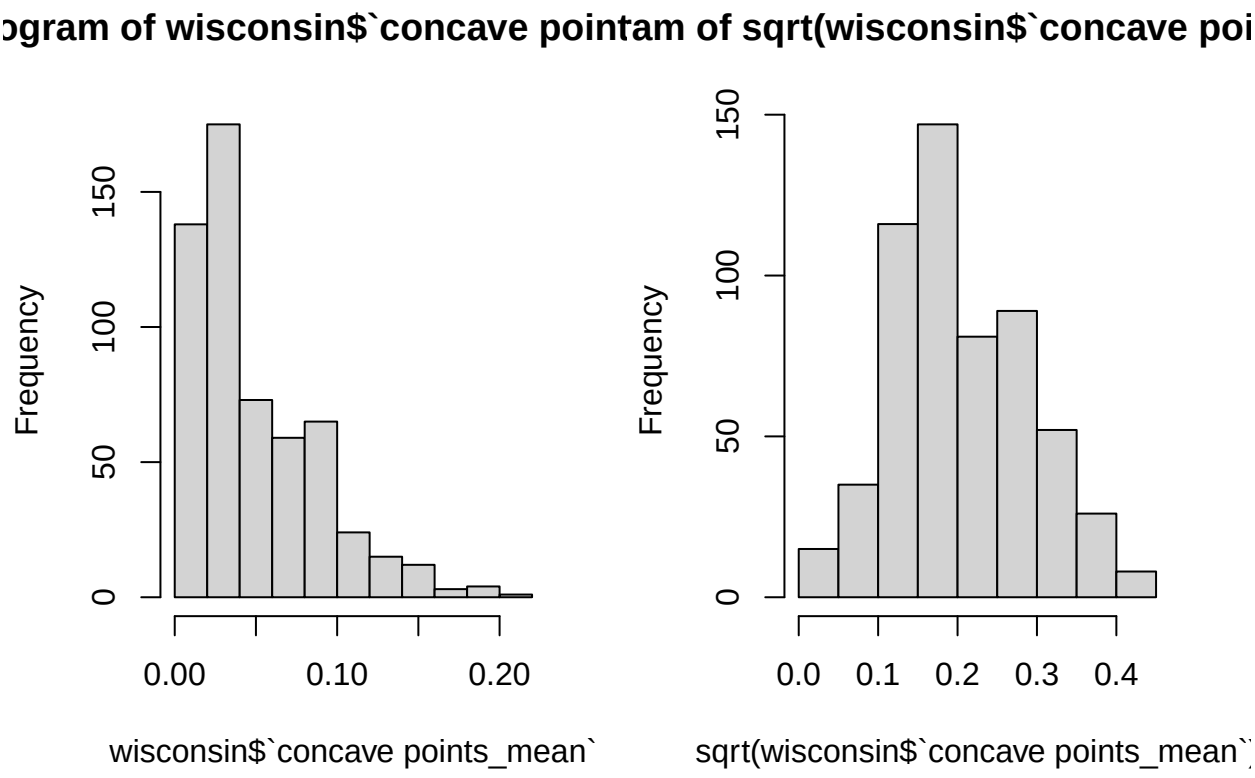
Mean area was not strongly right skewed. A log transformation of mean area resulted in a more symmetrical and normal distribution and will be proceeded with for further analysis.

```
par(mfrow = c(1,2))
hist(wisconsin$compactness_mean)
hist(log(wisconsin$compactness_mean))
```



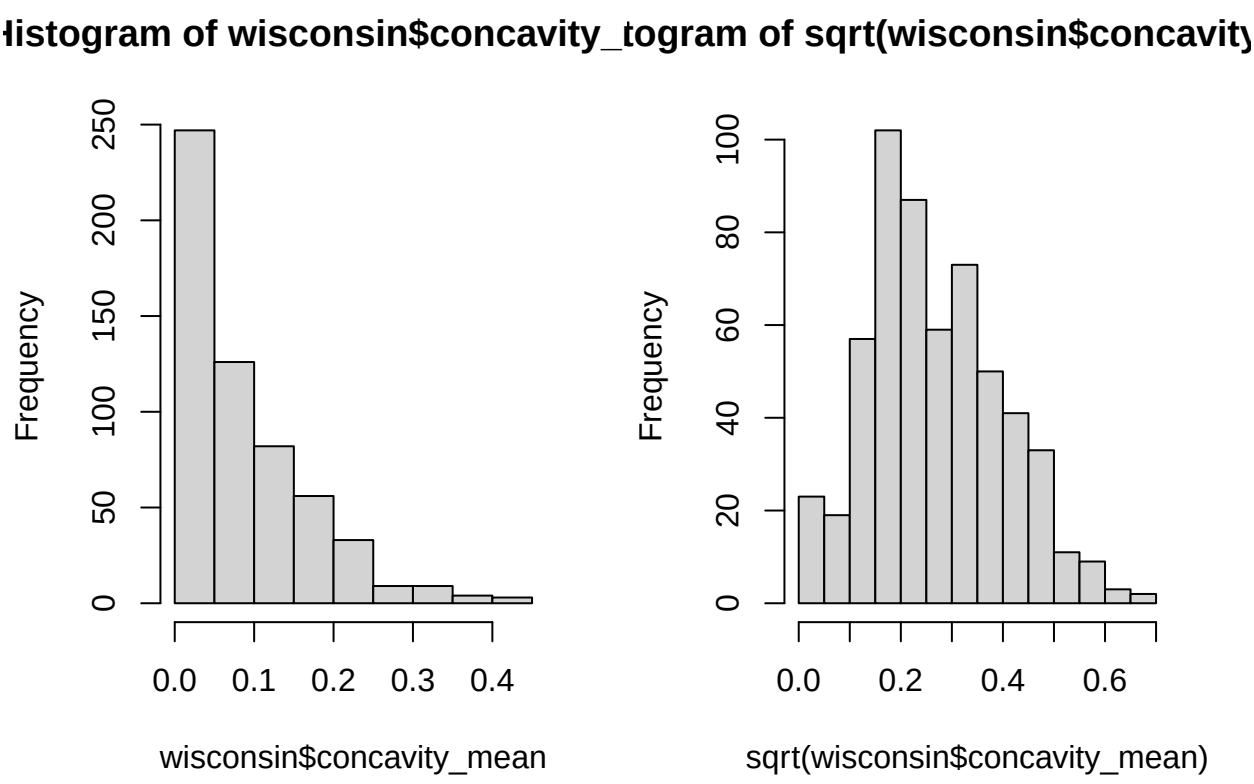
Mean compactness was strongly right skewed. A log transformation of mean compactness resulted in a more symmetrical and normal distribution and will be proceeded with in further analysis.

```
par(mfrow = c(1, 2))
hist(wisconsin$`concave points_mean`)
hist(sqrt(wisconsin$`concave points_mean`))
```



Mean concave points was severely skewed. A square root transformations resulted in a more symmetrical and normal distribution and will be proceeded with in further analysis.

```
par(mfrow = c(1, 2))
hist(wisconsin$concavity_mean)
hist(sqrt(wisconsin$concavity_mean))
```



Mean concavity is strongly skewed. A square root transformation resulted in a more symmetrical and normal distribution and will be proceeded with in further analysis.

```
#Adding transformations of area, compactness, concavity, and concave points
wisconsin$logarea_mean <- log(area_mean)
wisconsin$logcompactness_mean <- log(compactness_mean)
wisconsin$sqrtconcavity_mean <- sqrt(concavity_mean)
wisconsin$sqrtconcave_points_mean <- sqrt(concave_points_mean)
```

Histograms for the final set of predictor variables:

```
# Histograms of predictor variables
library(ggplot2)
library(tidyr)
```

```
## Warning: package 'tidyr' was built under R version 4.0.4
```

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 4.0.4
```

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

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

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

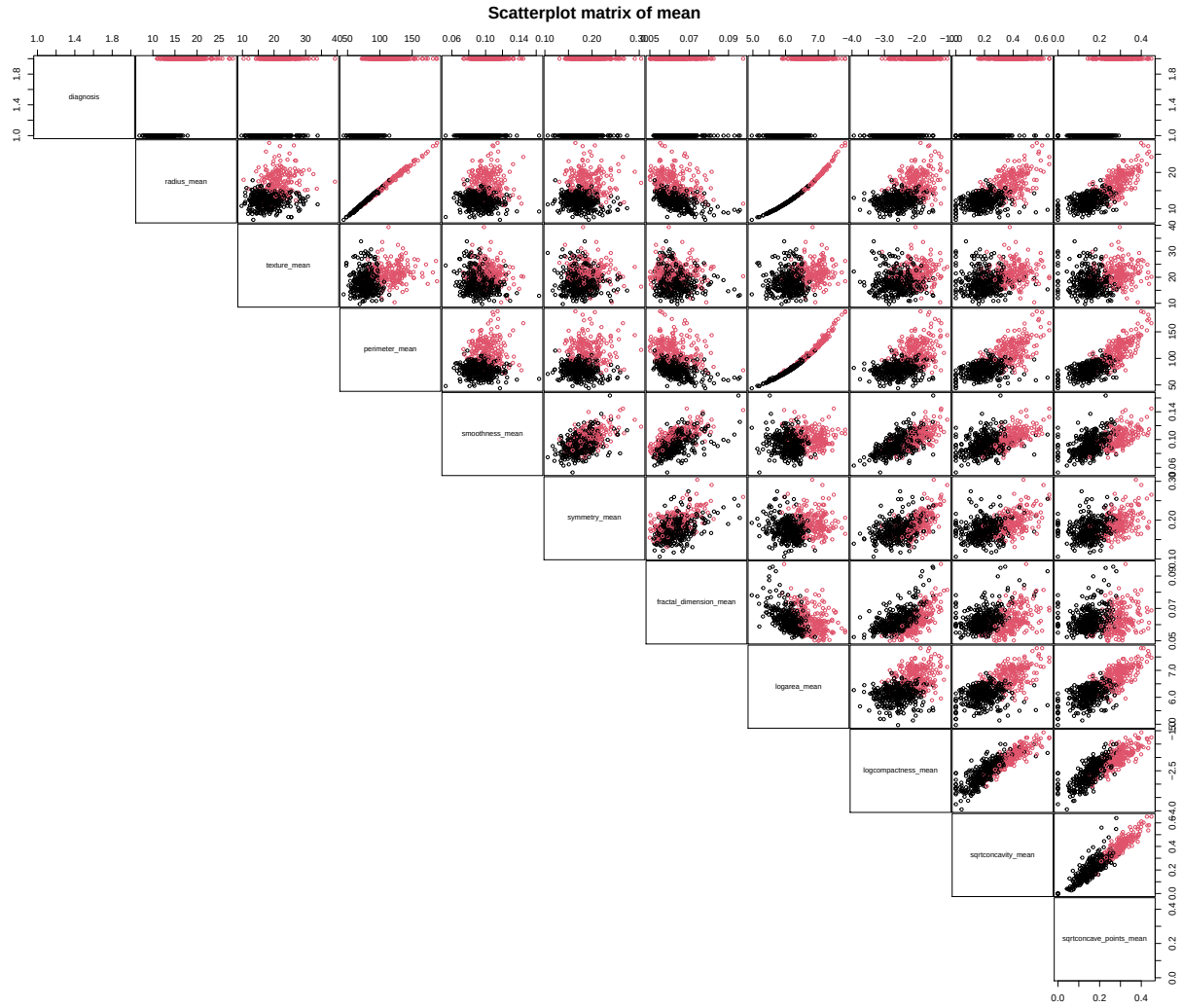
```
##     intersect, setdiff, setequal, union
```

```
plong = wisconsin[,c(1:4, 6, 10:15)] %>% group_by(diagnosis) %>%
  pivot_longer (2:11)

ggplot(plong, aes(value)) +
  geom_histogram(bins = 16, aes(fill=diagnosis, color=diagnosis), alpha=0.5, position = "identity") +
  facet_wrap(~name, scales = 'free_x')
```

A two way frequency table categorized by diagnosis shows that multiple predictor variables, particularly mean perimeter, log area, radius, log compactness, sqrt concave points, and sqrt concavity, are associated with diagnosis. Mean fractal dimension and symmetry appear as though they will be less predictive of diagnosis.

```
pairs(wisconsin[, c(1:4, 6, 10:15)], col=diagnosis, pch=1, cex = 0.75, lower.panel = NULL, gap = 0.1, ma
```




```
cormat= cor(wisconsin[, c(2:4, 6, 10:15)])
round(cormat,3)
```

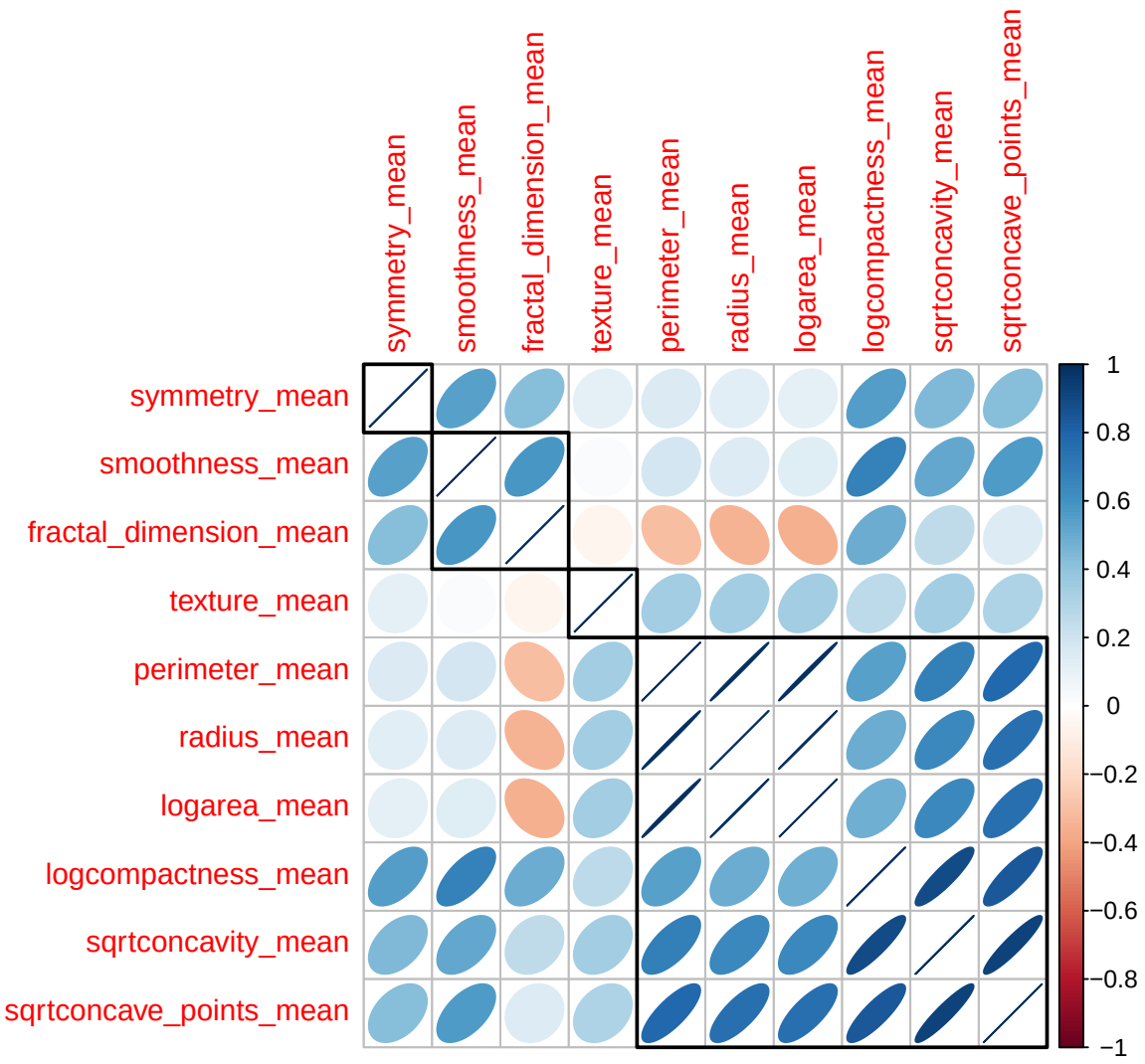
```
##                         radius_mean texture_mean perimeter_mean smoothness_mean
## radius_mean                   1.000        0.324          0.998           0.171
## texture_mean                  0.324        1.000          0.330          -0.023
## perimeter_mean                0.998        0.330          1.000           0.207
## smoothness_mean               0.171       -0.023          0.207           1.000
## symmetry_mean                 0.148        0.071          0.183           0.558
## fractal_dimension_mean       -0.312       -0.076         -0.261           0.585
## logarea_mean                  0.986        0.320          0.982           0.141
## logcompactness_mean           0.502        0.222          0.548           0.683
## sqrtconcavity_mean            0.680        0.294          0.716           0.527
## sqrtconcave_points_mean       0.798        0.268          0.824           0.563
##                         symmetry_mean fractal_dimension_mean logarea_mean
## radius_mean                     0.148                -0.312        0.986
## texture_mean                    0.071                -0.076        0.320
## perimeter_mean                  0.183                -0.261        0.982
## smoothness_mean                 0.558                 0.585        0.141
## symmetry_mean                   1.000                 0.480        0.120
```

```
## fractal_dimension_mean          0.480                 1.000       -0.356
## logarea_mean                    0.120                -0.356        1.000
## logcompactness_mean             0.562                 0.525        0.481
## sqrtconcavity_mean              0.468                 0.307        0.661
## sqrtconcave_points_mean         0.438                 0.158        0.787
##                         logcompactness_mean sqrtconcavity_mean
## radius_mean                           0.502               0.680
## texture_mean                          0.222               0.294
## perimeter_mean                        0.548               0.716
## smoothness_mean                       0.683               0.527
## symmetry_mean                         0.562               0.468
## fractal_dimension_mean                0.525               0.307
## logarea_mean                          0.481               0.661
## logcompactness_mean                   1.000               0.885
## sqrtconcavity_mean                    0.885               1.000
## sqrtconcave_points_mean               0.840               0.935
##                         sqrtconcave_points_mean
## radius_mean                               0.798
## texture_mean                              0.268
## perimeter_mean                            0.824
## smoothness_mean                           0.563
## symmetry_mean                             0.438
## fractal_dimension_mean                    0.158
## logarea_mean                              0.787
## logcompactness_mean                       0.840
## sqrtconcavity_mean                        0.935
## sqrtconcave_points_mean                   1.000
```

```
library(corrplot)
```

```
## corrplot 0.92 loaded
```

```
wisconsin.corr = cor(wisconsin[, c(2:4, 6, 10:15)], method = c("spearman"))
corrplot(wisconsin.corr, order ='hclust', method="ellipse", addrect = 4)
```



As expected, mean log area, mean perimeter, and mean radius are highly correlated given that they are functions of each other ($r > 0.982$). Many of our other predictors are correlated with each other. We will highlight some of the combinations that produce the strongest correlations. mean sqrt concavity and mean sqrt concave points are highly correlated with each other ($r = 0.935$). This suggests that the severity of concave portions of the cell is correlated with the number of concave portions on the cell contour. Log transformed mean compactness is correlated with mean sqrt concavity and mean sqrt concave points ($r =$ .885 and .840). As log transformed compactness increases so does mean sqrt concave points and mean sqrt concave points. There does not appear to be a logical explanation for why these predictors are correlated with each other. Issues with collinearity between the aforementioned correlated predictors should be considered when interpreting our output.

First Order Logistic Regression Model

We will now fit a first order logistic regression model that includes all of the variables. Log transformed mean area and compactness were included instead of the original variables. Similarly, categorized mean concavity and concave points were included instead of the original variables.

```
lm1 <- glm(diagnosis ~ radius_mean + texture_mean + perimeter_mean + smoothness_mean + symmetry_mean + 
summary(lm1)
```

```
##
## Call:
## glm(formula = diagnosis ~ radius_mean + texture_mean + perimeter_mean +
##     smoothness_mean + symmetry_mean + fractal_dimension_mean +
##     sqrtconcave_points_mean + sqrtconcavity_mean + logcompactness_mean +
##     logarea_mean, family = binomial, data = wisconsin)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.7933  -0.0980  -0.0124   0.0382   3.1847
##
## Coefficients:
##                           Estimate Std. Error z value Pr(>|z|)
## (Intercept)             -146.54110   51.61835  -2.839  0.00453 **
## radius_mean                1.27412    3.09951   0.411  0.68102
## texture_mean               0.39790    0.06756   5.889 3.88e-09 ***
## perimeter_mean            -0.47562    0.52334  -0.909  0.36345
## smoothness_mean           89.97401   37.52975   2.397  0.01651 *
## symmetry_mean             21.79649   11.65929   1.869  0.06156 .
## fractal_dimension_mean    27.18567   78.64810   0.346  0.72960
## sqrtconcave_points_mean   18.78152   13.57631   1.383  0.16654
## sqrtconcavity_mean        18.38916    6.71775   2.737  0.00619 **
## logcompactness_mean       -2.28134    2.08386  -1.095  0.27362
## logarea_mean              21.05942   10.88736   1.934  0.05308 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 751.44  on 568  degrees of freedom
## Residual deviance: 140.66  on 558  degrees of freedom
## AIC: 162.66
##
## Number of Fisher Scoring iterations: 8
```

```
exp(0.39790)
```

```
## [1] 1.488695
```

```
exp(89.97401/100)
```

```
## [1] 2.458964
```

```
exp(21.79649/10)
```

```
## [1] 8.843202
```

```
exp(18.38916/10)
```

```
## [1] 6.289717
```

```
exp(21.05942/10)
```

```
## [1] 8.214838
```

A preliminary analysis of our coefficients based on our first order model:

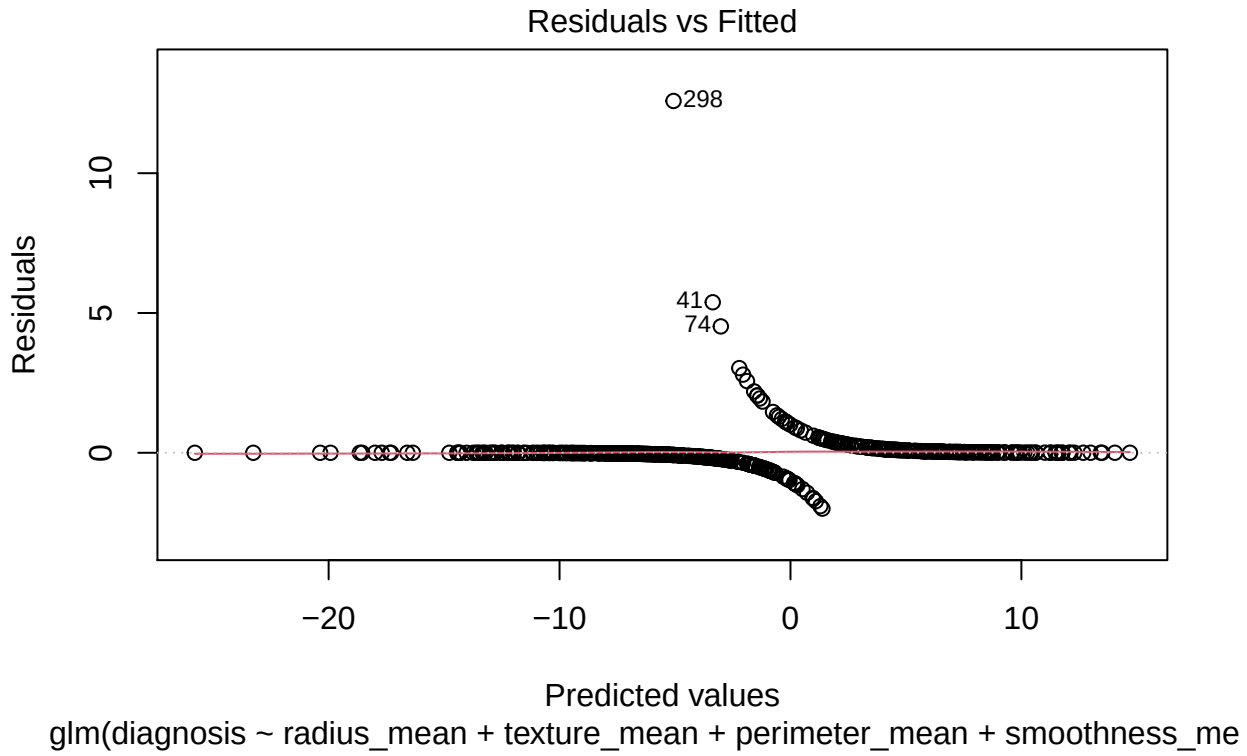
- Mean radius, perimeter, fractal dimension, sqrt concave points, and log compactness are not significantly associated with the odds of a tumor being malignant (p = 0.681, 0.363, 0.730, 0.167, and 0.274

respectively).

- For a one unit increase in mean cell texture, the odds of a tumor being malignant increases by a factor of 1.49, holding other predictors constant (p = 3.88e-09).
- For an increase of 0.01 in mean cell smoothness, the odds of a tumor being malignant increases by a factor of 2.46, holding other predictors constant (p = 0.01651).
- Holding other predictors constant, an increase of 0.1 in mean symmetry results in an increase in the odds of a tumor being malignant by a factor of 8.84, however this association is not quite significant (p = 0.06156).
- For an increase of 0.1 in mean concavity, the odds of a tumor being malignant increases by a factor of 6.29, holding other predictors constant (p = 0.00619).
- Holding other predictors constant, an increase of 0.1 in mean log area results in an increase in the odds of a tumor being malignant by a factor of 8.21, however this association is not quite significant (p = 0.05308).

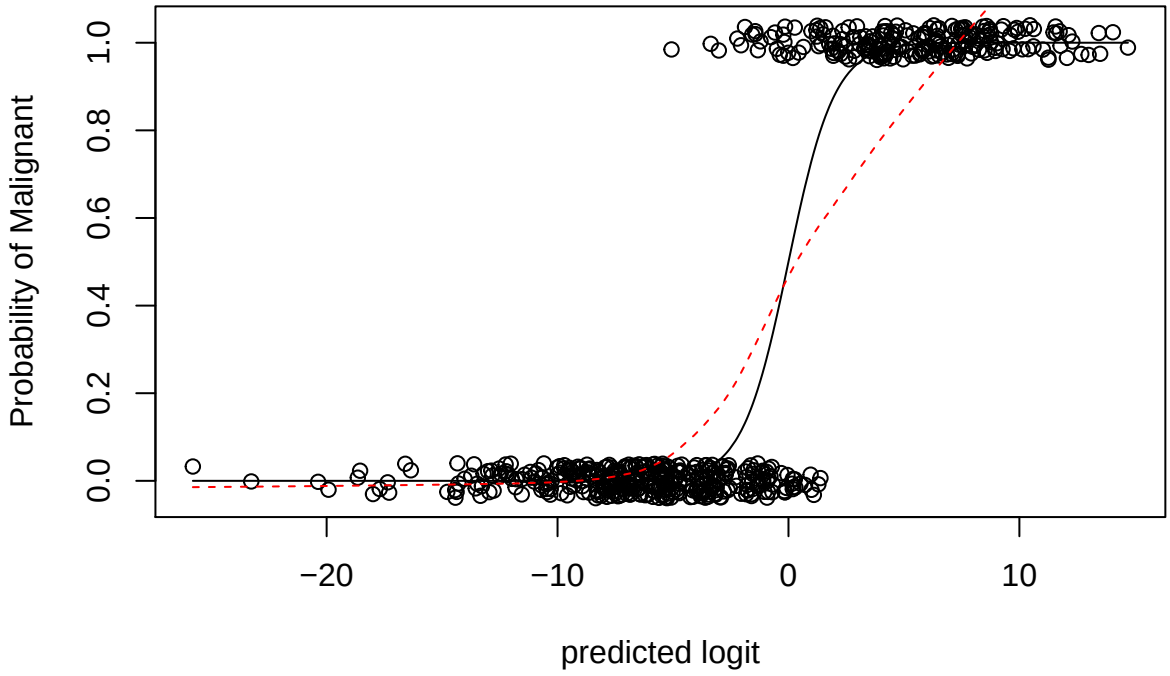
As previously mentioned, mean perimeter, radius, and log area are highly correlated. As a result, some of these correlated variables could be explaining similar variation in the log odds of a tumor being malignant. This should be taken into account when interpreting the coefficients and p values of these variables in the first order model.

```
par(mfrow=c(1,1))
plot(lm1, which = c(1))
```



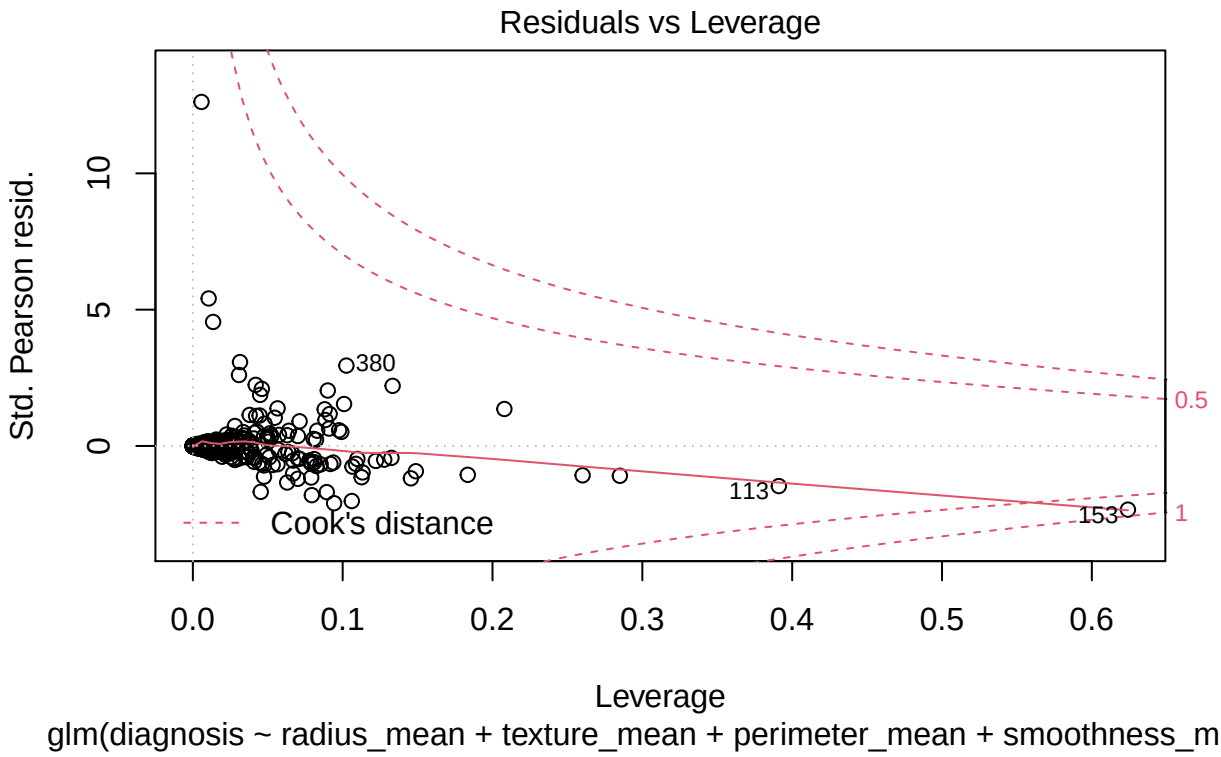
The smoothing spline in the residual plot for our first order model has little deviation from zero. Consequently, it appears that our model has successfully met the assumption of linearity.

```
predpr = predict (lm1, type='response')
predlogit = predict (lm1)
plot (jitter (ifelse(wisconsin$diagnosis=='M',1,0), 0.2) ~ predlogit, xlab="predicted logit", ylab="Prob
pred.ord = order (predlogit)
lines (predlogit[pred.ord], predpr[pred.ord])
lines (lowess (predlogit [pred.ord], predpr [pred.ord]), col='red', lty=2)
```



By observing the density of points, there is a clear switch from benign to malignant tumor cells near the predicted logit of 0. The clear switch with little overlap from benign to malignant tumor cell responses as predicted logit increases suggests that our model is likely well suited to accurately predict tumor diagnosis. A fitted smoothing spline line fits the general pattern of the fitted logistic curve however it diverges slightly. This suggests that the logistic model may not be representing the trend in the data as well as it could.

```
plot(lm1, which=5)
```



A plot of residuals vs leverage on the first order model shows that case 153 and 113 have high leverage. Point 153 is also a moderate influence point. Point 298, while not influential due to low leverage, has a very high residual.

```
car::vif(lm1)
```

```
##             radius_mean            texture_mean          perimeter_mean
##               571.049501                 1.784590               692.410572
##         smoothness_mean           symmetry_mean  fractal_dimension_mean
##                 4.649794                 1.927917                 6.678347
## sqrtconcave_points_mean      sqrtconcavity_mean     logcompactness_mean
##                 7.039467                 6.584806                11.814767
##            logarea_mean
##               141.186566
```

As could be expected from highly correlated predictors, our VIF values indicate that we have issues with collinearity. Particularly, we have collinearity issues with mean perimeter, radius, and log area (VIF values = 692.41, 571.05, and 141.19 respectively).

Stepwise regression on the first-order model

```
lm2 = step(lm1, direction = 'both')
```

```
## Start:  AIC=162.66
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + smoothness_mean +
##     symmetry_mean + fractal_dimension_mean + sqrtconcave_points_mean +
##     sqrtconcavity_mean + logcompactness_mean + logarea_mean
```

```
##
##                            Df Deviance    AIC
## - fractal_dimension_mean    1   140.78 160.78
## - radius_mean               1   140.83 160.83
## - perimeter_mean            1   141.46 161.46
## - logcompactness_mean       1   141.88 161.88
## - sqrtconcave_points_mean   1   142.65 162.65
## <none>                          140.66 162.66
## - symmetry_mean             1   144.19 164.19
## - logarea_mean              1   144.33 164.33
## - smoothness_mean           1   147.30 167.30
## - sqrtconcavity_mean        1   148.79 168.79
## - texture_mean              1   190.05 210.05
##
## Step:  AIC=160.78
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + smoothness_mean +
##     symmetry_mean + sqrtconcave_points_mean + sqrtconcavity_mean +
##     logcompactness_mean + logarea_mean
##
##                            Df Deviance    AIC
## - radius_mean               1   140.95 158.95
## - perimeter_mean            1   141.55 159.55
## - logcompactness_mean       1   141.89 159.89
## - sqrtconcave_points_mean   1   142.66 160.66
## <none>                          140.78 160.78
## - logarea_mean              1   144.34 162.34
## - symmetry_mean             1   144.42 162.42
## + fractal_dimension_mean    1   140.66 162.66
## - smoothness_mean           1   148.07 166.07
## - sqrtconcavity_mean        1   150.37 168.37
## - texture_mean              1   190.07 208.07
##
## Step:  AIC=158.95
## diagnosis ~ texture_mean + perimeter_mean + smoothness_mean +
##     symmetry_mean + sqrtconcave_points_mean + sqrtconcavity_mean +
##     logcompactness_mean + logarea_mean
##
##                            Df Deviance    AIC
## - perimeter_mean            1   142.28 158.28
## - sqrtconcave_points_mean   1   142.75 158.75
## <none>                          140.95 158.95
## - logarea_mean              1   144.48 160.48
## - symmetry_mean             1   144.62 160.62
## + radius_mean               1   140.78 160.78
## + fractal_dimension_mean    1   140.83 160.83
## - logcompactness_mean       1   145.11 161.11
## - smoothness_mean           1   149.06 165.06
## - sqrtconcavity_mean        1   150.45 166.45
## - texture_mean              1   190.43 206.43
##
## Step:  AIC=158.28
## diagnosis ~ texture_mean + smoothness_mean + symmetry_mean +
##     sqrtconcave_points_mean + sqrtconcavity_mean + logcompactness_mean +
##     logarea_mean
```

```
##
##                            Df Deviance    AIC
## - sqrtconcave_points_mean   1   144.04 158.04
## <none>                          142.28 158.28
## + perimeter_mean            1   140.95 158.95
## + radius_mean               1   141.55 159.55
## - symmetry_mean             1   145.59 159.59
## + fractal_dimension_mean    1   142.25 160.25
## - sqrtconcavity_mean        1   151.21 165.21
## - smoothness_mean           1   151.42 165.42
## - logcompactness_mean       1   151.75 165.75
## - logarea_mean              1   181.26 195.26
## - texture_mean              1   193.05 207.05
##
## Step:  AIC=158.04
## diagnosis ~ texture_mean + smoothness_mean + symmetry_mean +
##     sqrtconcavity_mean + logcompactness_mean + logarea_mean
##
##                            Df Deviance    AIC
## <none>                          144.04 158.04
## + sqrtconcave_points_mean   1   142.28 158.28
## + perimeter_mean            1   142.75 158.75
## - symmetry_mean             1   146.90 158.90
## + radius_mean               1   143.22 159.22
## + fractal_dimension_mean    1   144.04 160.04
## - logcompactness_mean       1   152.76 164.76
## - smoothness_mean           1   172.42 184.42
## - sqrtconcavity_mean        1   172.83 184.83
## - texture_mean              1   194.81 206.81
## - logarea_mean              1   302.62 314.62
```

```
summary(lm2)
```

```
##
## Call:
## glm(formula = diagnosis ~ texture_mean + smoothness_mean + symmetry_mean +
##     sqrtconcavity_mean + logcompactness_mean + logarea_mean,
##     family = binomial, data = wisconsin)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.8187  -0.1161  -0.0200   0.0226   3.2896
##
## Coefficients:
##                     Estimate Std. Error z value Pr(>|z|)
## (Intercept)         -97.8137    12.7062  -7.698 1.38e-14 ***
## texture_mean          0.3962     0.0658   6.022 1.73e-09 ***
## smoothness_mean     129.7312    27.5952   4.701 2.59e-06 ***
## symmetry_mean        18.8677    11.2616   1.675  0.09385 .
## sqrtconcavity_mean   23.0600     4.5989   5.014 5.32e-07 ***
## logcompactness_mean  -3.2733     1.1556  -2.833  0.00462 **
## logarea_mean          9.2641     1.2357   7.497 6.54e-14 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
```

```
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 751.44  on 568  degrees of freedom
## Residual deviance: 144.04  on 562  degrees of freedom
## AIC: 158.04
##
## Number of Fisher Scoring iterations: 8
```

Our step wise regression using AIC criteria removed in order mean fractal dimension, radius, perimeter, and sqrt concave points. This resulted in a model that included mean texture, smoothness, sqrt concavity, log compactness, log area, and symmetry. All predictors were significant with the exception of mean symmetry for which the p value did not quite meet the 0.05 threshold ($p = 0.094$). The AIC was minimized with this combination of predictors included in the model at 158.04. For comparison, the AIC of the full first order model was 162.66.

Creating centered interaction effects

We will create centered interaction effects to hopefully counteract the previously identified collinearity issues.

```
my.center = function (x) (x - mean(x))
wisconsin$texture_mean.c = my.center(wisconsin$texture_mean)
wisconsin$smoothness_mean.c = my.center(wisconsin$smoothness_mean)
wisconsin$symmetry_mean.c = my.center(wisconsin$symmetry_mean)
wisconsin$sqrtconcavity_mean.c = my.center(wisconsin$sqrtconcavity_mean)
wisconsin$sqrtconcave_points_mean.c = my.center(wisconsin$`concave points_mean`)
wisconsin$logcompactness_mean.c = my.center(wisconsin$logcompactness_mean)
wisconsin$logarea_mean.c = my.center(wisconsin$logarea_mean)
```

Fit a model with interactions

Only the predictors kept from the step wise regression on the first order model were centered and used in the interaction model to avoid convergence errors.

```
lm3 = glm(diagnosis ~ (texture_mean.c + smoothness_mean.c + symmetry_mean.c + sqrtconcavity_mean.c + sq
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
summary(lm3)
```

```
##
## Call:
## glm(formula = diagnosis ~ (texture_mean.c + smoothness_mean.c +
##     symmetry_mean.c + sqrtconcavity_mean.c + sqrtconcave_points_mean.c +
##     logcompactness_mean.c + logarea_mean.c)^2, family = binomial,
##     data = wisconsin)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -1.9841  -0.0650  -0.0084   0.0002   3.4694
##
## Coefficients:
##                                                 Estimate Std. Error z value
## (Intercept)                                    4.878e-03  6.429e-01   0.008
## texture_mean.c                                 5.760e-01  1.697e-01   3.395
## smoothness_mean.c                              1.219e+02  7.321e+01   1.666
```

```
## symmetry_mean.c                                    2.466e+01  3.043e+01   0.810
## sqrtconcavity_mean.c                               4.909e+01  1.444e+01   3.400
## sqrtconcave_points_mean.c                          6.181e+01  5.666e+01   1.091
## logcompactness_mean.c                             -8.091e+00  2.885e+00  -2.805
## logarea_mean.c                                     9.067e+00  2.787e+00   3.254
## texture_mean.c:smoothness_mean.c                   5.493e+01  2.237e+01   2.455
## texture_mean.c:symmetry_mean.c                     4.995e+00  7.343e+00   0.680
## texture_mean.c:sqrtconcavity_mean.c                5.449e+00  3.559e+00   1.531
## texture_mean.c:sqrtconcave_points_mean.c          -1.394e+01  1.692e+01  -0.824
## texture_mean.c:logcompactness_mean.c              -1.482e+00  7.645e-01  -1.939
## texture_mean.c:logarea_mean.c                      1.733e+00  6.933e-01   2.500
## smoothness_mean.c:symmetry_mean.c                 -6.726e+02  2.389e+03  -0.282
## smoothness_mean.c:sqrtconcavity_mean.c             5.193e+03  2.008e+03   2.586
## smoothness_mean.c:sqrtconcave_points_mean.c       -1.205e+04  6.484e+03  -1.858
## smoothness_mean.c:logcompactness_mean.c           -2.126e+02  3.201e+02  -0.664
## smoothness_mean.c:logarea_mean.c                  -1.655e+02  1.529e+02  -1.083
## symmetry_mean.c:sqrtconcavity_mean.c              -3.759e+02  7.131e+02  -0.527
## symmetry_mean.c:sqrtconcave_points_mean.c          2.283e+03  2.775e+03   0.823
## symmetry_mean.c:logcompactness_mean.c              5.014e+01  1.400e+02   0.358
## symmetry_mean.c:logarea_mean.c                    -1.698e+01  9.548e+01  -0.178
## sqrtconcavity_mean.c:sqrtconcave_points_mean.c     3.321e+02  1.031e+03   0.322
## sqrtconcavity_mean.c:logcompactness_mean.c        -6.203e+01  4.598e+01  -1.349
## sqrtconcavity_mean.c:logarea_mean.c                9.309e+01  5.842e+01   1.593
## sqrtconcave_points_mean.c:logcompactness_mean.c    7.175e+01  2.791e+02   0.257
## sqrtconcave_points_mean.c:logarea_mean.c          -2.941e+02  2.264e+02  -1.299
## logcompactness_mean.c:logarea_mean.c               2.835e+00  1.073e+01   0.264
##                                                   Pr(>|z|)
## (Intercept)                                       0.993946
## texture_mean.c                                    0.000686 ***
## smoothness_mean.c                                 0.095807 .
## symmetry_mean.c                                   0.417783
## sqrtconcavity_mean.c                              0.000675 ***
## sqrtconcave_points_mean.c                         0.275292
## logcompactness_mean.c                             0.005038 **
## logarea_mean.c                                    0.001139 **
## texture_mean.c:smoothness_mean.c                  0.014072 *
## texture_mean.c:symmetry_mean.c                    0.496401
## texture_mean.c:sqrtconcavity_mean.c               0.125707
## texture_mean.c:sqrtconcave_points_mean.c          0.410203
## texture_mean.c:logcompactness_mean.c              0.052512 .
## texture_mean.c:logarea_mean.c                     0.012416 *
## smoothness_mean.c:symmetry_mean.c                 0.778258
## smoothness_mean.c:sqrtconcavity_mean.c            0.009710 **
## smoothness_mean.c:sqrtconcave_points_mean.c       0.063159 .
## smoothness_mean.c:logcompactness_mean.c           0.506480
## smoothness_mean.c:logarea_mean.c                  0.278941
## symmetry_mean.c:sqrtconcavity_mean.c              0.598137
## symmetry_mean.c:sqrtconcave_points_mean.c         0.410543
## symmetry_mean.c:logcompactness_mean.c             0.720131
## symmetry_mean.c:logarea_mean.c                    0.858880
## sqrtconcavity_mean.c:sqrtconcave_points_mean.c    0.747365
## sqrtconcavity_mean.c:logcompactness_mean.c        0.177269
## sqrtconcavity_mean.c:logarea_mean.c               0.111098
## sqrtconcave_points_mean.c:logcompactness_mean.c   0.797088
```

```
## sqrtconcave_points_mean.c:logarea_mean.c       0.194012
## logcompactness_mean.c:logarea_mean.c           0.791645
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 751.440  on 568  degrees of freedom
## Residual deviance:  81.934  on 540  degrees of freedom
## AIC: 139.93
##
## Number of Fisher Scoring iterations: 12
```

In this full second order model with centered predictors and interactions we find that mean texture, sqrt concavity, log compactness, and log compactness are significant predictors of tumor diagnosis. There are significant interactions between smoothness and texture, texture and log area, and between smoothness and sqrt concavity. The AIC of this model at 139.93 than the model generated from step wise regression of the full first order model without centered predictors at 158.04.

Applying stepwise regression to the full second order model

AIC

```
lm4 = step(lm3, direction='both', )
```

```
## Start:  AIC=139.93
## diagnosis ~ (texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c)^2
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                 Df Deviance    AIC
## - symmetry_mean.c:logarea_mean.c                 1   81.963 137.96
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.001 138.00
## - logcompactness_mean.c:logarea_mean.c           1   82.002 138.00
## - smoothness_mean.c:symmetry_mean.c              1   82.011 138.01
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.036 138.04
## - symmetry_mean.c:logcompactness_mean.c          1   82.061 138.06
## - symmetry_mean.c:sqrtconcavity_mean.c           1   82.214 138.21
## - smoothness_mean.c:logcompactness_mean.c        1   82.402 138.40
## - texture_mean.c:symmetry_mean.c                 1   82.478 138.48
## - texture_mean.c:sqrtconcave_points_mean.c       1   82.581 138.58
## - symmetry_mean.c:sqrtconcave_points_mean.c      1   82.620 138.62
## - smoothness_mean.c:logarea_mean.c               1   82.992 138.99
## - sqrtconcave_points_mean.c:logarea_mean.c       1   83.897 139.90
## <none>                                               81.934 139.93
## - sqrtconcavity_mean.c:logcompactness_mean.c     1   84.487 140.49
## - texture_mean.c:sqrtconcavity_mean.c            1   84.509 140.51
## - sqrtconcavity_mean.c:logarea_mean.c            1   85.317 141.32
## - texture_mean.c:logcompactness_mean.c           1   87.013 143.01
## - smoothness_mean.c:sqrtconcave_points_mean.c    1   87.419 143.42
## - texture_mean.c:logarea_mean.c                  1   89.449 145.45
## - texture_mean.c:smoothness_mean.c               1   91.005 147.00
## - smoothness_mean.c:sqrtconcavity_mean.c         1   97.910 153.91

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=137.96
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:symmetry_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcavity_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + symmetry_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
```

```
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c + logcompactness_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                    Df Deviance    AIC
## - logcompactness_mean.c:logarea_mean.c              1   82.013 136.01
## - smoothness_mean.c:symmetry_mean.c                 1   82.015 136.01
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.029 136.03
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.059 136.06
## - symmetry_mean.c:logcompactness_mean.c            1   82.090 136.09
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.220 136.22
## - smoothness_mean.c:logcompactness_mean.c          1   82.428 136.43
```

```
## - texture_mean.c:symmetry_mean.c                   1   82.541 136.54
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.619 136.62
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   82.625 136.62
## - smoothness_mean.c:logarea_mean.c                 1   83.011 137.01
## - sqrtconcave_points_mean.c:logarea_mean.c         1   83.908 137.91
## <none>                                                 81.963 137.96
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.495 138.50
## - texture_mean.c:sqrtconcavity_mean.c              1   84.509 138.51
## - sqrtconcavity_mean.c:logarea_mean.c              1   85.350 139.35
## + symmetry_mean.c:logarea_mean.c                   1   81.934 139.93
## - texture_mean.c:logcompactness_mean.c             1   87.018 141.02
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   87.420 141.42
## - texture_mean.c:logarea_mean.c                    1   89.489 143.49
## - texture_mean.c:smoothness_mean.c                 1   91.018 145.02
## - smoothness_mean.c:sqrtconcavity_mean.c           1   98.274 152.27
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=136.01
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:symmetry_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcavity_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + symmetry_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                Df Deviance    AIC
## - smoothness_mean.c:symmetry_mean.c             1   82.057 134.06
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.071 134.07
## - symmetry_mean.c:logcompactness_mean.c         1   82.105 134.10
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.166 134.17
## - symmetry_mean.c:sqrtconcavity_mean.c          1   82.223 134.22
## - texture_mean.c:symmetry_mean.c                1   82.565 134.56
## - texture_mean.c:sqrtconcave_points_mean.c      1   82.651 134.65
## - symmetry_mean.c:sqrtconcave_points_mean.c     1   82.664 134.66
## - smoothness_mean.c:logcompactness_mean.c       1   82.812 134.81
## - smoothness_mean.c:logarea_mean.c              1   83.049 135.05
## - sqrtconcave_points_mean.c:logarea_mean.c      1   83.948 135.95
## <none>                                             82.013 136.01
## - sqrtconcavity_mean.c:logcompactness_mean.c    1   84.500 136.50
## - texture_mean.c:sqrtconcavity_mean.c           1   84.513 136.51
## + logcompactness_mean.c:logarea_mean.c          1   81.963 137.96
## + symmetry_mean.c:logarea_mean.c                1   82.002 138.00
## - texture_mean.c:logcompactness_mean.c          1   87.038 139.04
## - sqrtconcavity_mean.c:logarea_mean.c           1   87.197 139.20
## - smoothness_mean.c:sqrtconcave_points_mean.c   1   87.542 139.54
## - texture_mean.c:logarea_mean.c                 1   89.556 141.56
## - texture_mean.c:smoothness_mean.c              1   91.080 143.08
## - smoothness_mean.c:sqrtconcavity_mean.c        1   98.277 150.28
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=134.06
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
```

```
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     symmetry_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                   Df Deviance    AIC
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.090 132.09
## - symmetry_mean.c:logcompactness_mean.c            1   82.110 132.11
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.232 132.23
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.296 132.30
## - texture_mean.c:symmetry_mean.c                   1   82.598 132.60
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.682 132.68
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   82.690 132.69
## - smoothness_mean.c:logarea_mean.c                 1   83.091 133.09
## - smoothness_mean.c:logcompactness_mean.c          1   83.118 133.12
## <none>                                                 82.057 134.06
## - sqrtconcave_points_mean.c:logarea_mean.c         1   84.112 134.11
## - texture_mean.c:sqrtconcavity_mean.c              1   84.613 134.61
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.861 134.86
## + smoothness_mean.c:symmetry_mean.c                1   82.013 136.01
## + logcompactness_mean.c:logarea_mean.c             1   82.015 136.01
## + symmetry_mean.c:logarea_mean.c                   1   82.057 136.06
## - texture_mean.c:logcompactness_mean.c             1   87.319 137.32
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   88.173 138.17
## - sqrtconcavity_mean.c:logarea_mean.c              1   88.464 138.46
## - texture_mean.c:logarea_mean.c                    1   89.685 139.69
## - texture_mean.c:smoothness_mean.c                 1   91.176 141.18
## - smoothness_mean.c:sqrtconcavity_mean.c           1  100.635 150.63
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=132.09
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     symmetry_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                   Df Deviance    AIC
## - symmetry_mean.c:logcompactness_mean.c            1   82.122 130.12
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.237 130.24
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.595 130.59
## - texture_mean.c:symmetry_mean.c                   1   82.662 130.66
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   82.731 130.73
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.742 130.74
## - smoothness_mean.c:logarea_mean.c                 1   83.161 131.16
## - smoothness_mean.c:logcompactness_mean.c          1   83.883 131.88
## <none>                                                 82.090 132.09
## - sqrtconcave_points_mean.c:logarea_mean.c         1   84.113 132.11
## - texture_mean.c:sqrtconcavity_mean.c              1   84.743 132.74
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.880 132.88
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.057 134.06
## + smoothness_mean.c:symmetry_mean.c                1   82.071 134.07
## + logcompactness_mean.c:logarea_mean.c             1   82.076 134.08
## + symmetry_mean.c:logarea_mean.c                   1   82.087 134.09
## - texture_mean.c:logcompactness_mean.c             1   87.320 135.32
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   88.205 136.21
## - sqrtconcavity_mean.c:logarea_mean.c              1   89.649 137.65
## - texture_mean.c:logarea_mean.c                    1   89.792 137.79
## - texture_mean.c:smoothness_mean.c                 1   91.400 139.40
## - smoothness_mean.c:sqrtconcavity_mean.c           1  102.307 150.31

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=130.12
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
```

```
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                    Df Deviance    AIC
## - symmetry_mean.c:sqrtconcavity_mean.c              1   82.237 128.24
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.611 128.61
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.784 128.78
## - texture_mean.c:symmetry_mean.c                   1   82.797 128.80
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   83.007 129.01
## - smoothness_mean.c:logarea_mean.c                 1   83.233 129.23
## <none>                                                 82.122 130.12
## - sqrtconcave_points_mean.c:logarea_mean.c         1   84.297 130.30
## - smoothness_mean.c:logcompactness_mean.c          1   84.402 130.40
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.893 130.89
## - texture_mean.c:sqrtconcavity_mean.c              1   85.032 131.03
## + symmetry_mean.c:logcompactness_mean.c            1   82.090 132.09
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.110 132.11
## + symmetry_mean.c:logarea_mean.c                   1   82.113 132.11
## + logcompactness_mean.c:logarea_mean.c             1   82.114 132.11
## + smoothness_mean.c:symmetry_mean.c                1   82.119 132.12
## - texture_mean.c:logcompactness_mean.c             1   88.438 134.44
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   89.510 135.51
## - texture_mean.c:logarea_mean.c                    1   89.807 135.81
## - sqrtconcavity_mean.c:logarea_mean.c              1   90.698 136.70
## - texture_mean.c:smoothness_mean.c                 1   91.629 137.63
## - smoothness_mean.c:sqrtconcavity_mean.c           1  102.310 148.31
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=128.24
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                    Df Deviance    AIC
## - texture_mean.c:symmetry_mean.c                    1   82.865 126.86
## - texture_mean.c:sqrtconcave_points_mean.c          1   82.893 126.89
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.028 127.03
## - smoothness_mean.c:logarea_mean.c                  1   83.452 127.45
## - symmetry_mean.c:sqrtconcave_points_mean.c         1   83.764 127.76
## <none>                                                 82.237 128.24
## - smoothness_mean.c:logcompactness_mean.c           1   84.411 128.41
## - texture_mean.c:sqrtconcavity_mean.c               1   85.445 129.44
## - sqrtconcave_points_mean.c:logarea_mean.c          1   85.491 129.49
## + symmetry_mean.c:sqrtconcavity_mean.c              1   82.122 130.12
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.233 130.23
## + smoothness_mean.c:symmetry_mean.c                 1   82.233 130.23
## + logcompactness_mean.c:logarea_mean.c              1   82.236 130.24
## + symmetry_mean.c:logarea_mean.c                    1   82.236 130.24
## + symmetry_mean.c:logcompactness_mean.c             1   82.237 130.24
## - sqrtconcavity_mean.c:logcompactness_mean.c        1   87.298 131.30
## - texture_mean.c:logcompactness_mean.c              1   88.669 132.67
## - texture_mean.c:logarea_mean.c                     1   89.830 133.83
## - smoothness_mean.c:sqrtconcave_points_mean.c       1   89.844 133.84
## - texture_mean.c:smoothness_mean.c                  1   91.631 135.63
## - sqrtconcavity_mean.c:logarea_mean.c               1   96.411 140.41
## - smoothness_mean.c:sqrtconcavity_mean.c            1  104.483 148.48

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=126.86
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
```

```
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:sqrtconcave_points_mean.c + texture_mean.c:logcompactness_mean.c +
##     texture_mean.c:logarea_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                    Df Deviance    AIC
## - texture_mean.c:sqrtconcave_points_mean.c         1   83.829 125.83
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.895 125.89
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   84.195 126.19
## - smoothness_mean.c:logarea_mean.c                 1   84.456 126.46
## <none>                                                 82.865 126.86
## - smoothness_mean.c:logcompactness_mean.c          1   85.327 127.33
## + texture_mean.c:symmetry_mean.c                   1   82.237 128.24
## - sqrtconcave_points_mean.c:logarea_mean.c         1   86.472 128.47
## + symmetry_mean.c:sqrtconcavity_mean.c             1   82.797 128.80
## + symmetry_mean.c:logarea_mean.c                   1   82.816 128.82
## + symmetry_mean.c:logcompactness_mean.c            1   82.829 128.83
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.853 128.85
## + smoothness_mean.c:symmetry_mean.c                1   82.860 128.86
## + logcompactness_mean.c:logarea_mean.c             1   82.861 128.86
## - texture_mean.c:sqrtconcavity_mean.c              1   88.158 130.16
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   88.650 130.65
## - texture_mean.c:logcompactness_mean.c             1   88.913 130.91
## - texture_mean.c:logarea_mean.c                    1   90.112 132.11
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   91.215 133.22
## - texture_mean.c:smoothness_mean.c                 1   94.619 136.62
## - sqrtconcavity_mean.c:logarea_mean.c              1   97.787 139.79
## - smoothness_mean.c:sqrtconcavity_mean.c           1  105.900 147.90
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=125.83
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
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```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                   Df Deviance    AIC
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   84.681 124.68
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   84.952 124.95
## - smoothness_mean.c:logarea_mean.c                 1   85.401 125.40
## <none>                                                 83.829 125.83
## - sqrtconcave_points_mean.c:logarea_mean.c         1   86.478 126.48
## - smoothness_mean.c:logcompactness_mean.c          1   86.590 126.59
## + texture_mean.c:sqrtconcave_points_mean.c         1   82.865 126.86
## + texture_mean.c:symmetry_mean.c                   1   82.893 126.89
## + symmetry_mean.c:logarea_mean.c                   1   83.737 127.74
## + symmetry_mean.c:sqrtconcavity_mean.c             1   83.741 127.74
## + symmetry_mean.c:logcompactness_mean.c            1   83.785 127.78
## + logcompactness_mean.c:logarea_mean.c             1   83.809 127.81
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   83.809 127.81
## + smoothness_mean.c:symmetry_mean.c                1   83.818 127.82
## - texture_mean.c:sqrtconcavity_mean.c              1   88.170 128.17
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   89.210 129.21
## - texture_mean.c:logarea_mean.c                    1   90.649 130.65
## - texture_mean.c:logcompactness_mean.c             1   90.816 130.82
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   91.259 131.26
## - texture_mean.c:smoothness_mean.c                 1   95.845 135.84
## - sqrtconcavity_mean.c:logarea_mean.c              1   97.891 137.89
## - smoothness_mean.c:sqrtconcavity_mean.c           1  106.100 146.10

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=124.68
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
```

```
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                   Df Deviance    AIC
## - smoothness_mean.c:logarea_mean.c                 1   86.393 124.39
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   86.415 124.42
## - sqrtconcave_points_mean.c:logarea_mean.c         1   86.543 124.54
```

```
## - smoothness_mean.c:logcompactness_mean.c          1   86.671 124.67
## <none>                                                 84.681 124.68
## + texture_mean.c:symmetry_mean.c                   1   83.523 125.52
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.829 125.83
## + texture_mean.c:sqrtconcave_points_mean.c         1   83.895 125.89
## + symmetry_mean.c:sqrtconcavity_mean.c             1   84.333 126.33
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   84.389 126.39
## + smoothness_mean.c:symmetry_mean.c                1   84.638 126.64
## + logcompactness_mean.c:logarea_mean.c             1   84.679 126.68
## + symmetry_mean.c:logarea_mean.c                   1   84.680 126.68
## + symmetry_mean.c:logcompactness_mean.c            1   84.680 126.68
## - texture_mean.c:sqrtconcavity_mean.c              1   89.842 127.84
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   90.346 128.35
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   91.371 129.37
## - texture_mean.c:logarea_mean.c                    1   93.086 131.09
## - texture_mean.c:logcompactness_mean.c             1   95.507 133.51
## - sqrtconcavity_mean.c:logarea_mean.c              1   98.398 136.40
## - texture_mean.c:smoothness_mean.c                 1  103.921 141.92
## - smoothness_mean.c:sqrtconcavity_mean.c           1  106.847 144.85
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=124.39
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                 Df Deviance    AIC
## - smoothness_mean.c:logcompactness_mean.c         1   87.590 123.59
## - symmetry_mean.c:sqrtconcave_points_mean.c       1   87.936 123.94
## <none>                                                86.393 124.39
## + smoothness_mean.c:logarea_mean.c                1   84.681 124.68
## + texture_mean.c:symmetry_mean.c                  1   84.804 124.80
## + sqrtconcave_points_mean.c:logcompactness_mean.c 1   85.401 125.40
## + texture_mean.c:sqrtconcave_points_mean.c        1   85.537 125.54
## - sqrtconcave_points_mean.c:logarea_mean.c        1   89.747 125.75
## + symmetry_mean.c:sqrtconcavity_mean.c            1   85.906 125.91
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c  1   85.922 125.92
## + logcompactness_mean.c:logarea_mean.c            1   86.000 126.00
## + symmetry_mean.c:logarea_mean.c                  1   86.365 126.36
## + symmetry_mean.c:logcompactness_mean.c           1   86.384 126.38
## + smoothness_mean.c:symmetry_mean.c               1   86.390 126.39
## - texture_mean.c:sqrtconcavity_mean.c             1   92.066 128.07
## - sqrtconcavity_mean.c:logcompactness_mean.c      1   92.120 128.12
## - smoothness_mean.c:sqrtconcave_points_mean.c     1   93.333 129.33
## - texture_mean.c:logarea_mean.c                   1   94.615 130.62
## - texture_mean.c:logcompactness_mean.c            1   97.614 133.61
## - sqrtconcavity_mean.c:logarea_mean.c             1   98.928 134.93
## - texture_mean.c:smoothness_mean.c                1  104.933 140.93
## - smoothness_mean.c:sqrtconcavity_mean.c          1  107.124 143.12

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=123.59
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
```

```
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                   Df Deviance    AIC
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   89.333 123.33
## <none>                                                 87.590 123.59
## + texture_mean.c:symmetry_mean.c                   1   85.965 123.97
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   86.043 124.04
## + smoothness_mean.c:logcompactness_mean.c          1   86.393 124.39
## - sqrtconcave_points_mean.c:logarea_mean.c         1   90.458 124.46
## + texture_mean.c:sqrtconcave_points_mean.c         1   86.553 124.55
```

```
## + smoothness_mean.c:logarea_mean.c                 1   86.671 124.67
## + smoothness_mean.c:symmetry_mean.c                 1   87.364 125.36
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   87.378 125.38
## + symmetry_mean.c:logcompactness_mean.c            1   87.467 125.47
## + symmetry_mean.c:sqrtconcavity_mean.c             1   87.518 125.52
## + logcompactness_mean.c:logarea_mean.c             1   87.541 125.54
## + symmetry_mean.c:logarea_mean.c                   1   87.583 125.58
## - texture_mean.c:sqrtconcavity_mean.c              1   92.066 126.07
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   95.391 129.39
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   95.867 129.87
## - texture_mean.c:logarea_mean.c                    1   96.860 130.86
## - texture_mean.c:logcompactness_mean.c             1   97.656 131.66
## - sqrtconcavity_mean.c:logarea_mean.c              1   99.340 133.34
## - texture_mean.c:smoothness_mean.c                 1  106.059 140.06
## - smoothness_mean.c:sqrtconcavity_mean.c           1  109.846 143.85
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=123.33
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                Df Deviance    AIC
## - symmetry_mean.c                               1   90.628 122.63
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c 1   86.900 122.90
## <none>                                             89.333 123.33
## + symmetry_mean.c:sqrtconcave_points_mean.c      1   87.590 123.59
## + smoothness_mean.c:logcompactness_mean.c        1   87.936 123.94
## + texture_mean.c:sqrtconcave_points_mean.c       1   88.072 124.07
## - sqrtconcave_points_mean.c:logarea_mean.c       1   92.146 124.15
## + smoothness_mean.c:logarea_mean.c               1   88.303 124.30
## + sqrtconcave_points_mean.c:logcompactness_mean.c 1   88.463 124.46
## + symmetry_mean.c:sqrtconcavity_mean.c           1   88.473 124.47
## + texture_mean.c:symmetry_mean.c                 1   88.568 124.57
## + symmetry_mean.c:logcompactness_mean.c          1   88.689 124.69
## - texture_mean.c:sqrtconcavity_mean.c            1   92.839 124.84
## + logcompactness_mean.c:logarea_mean.c           1   89.091 125.09
## + smoothness_mean.c:symmetry_mean.c              1   89.233 125.23
## + symmetry_mean.c:logarea_mean.c                 1   89.304 125.30
## - smoothness_mean.c:sqrtconcave_points_mean.c    1   95.409 127.41
## - sqrtconcavity_mean.c:logcompactness_mean.c     1   95.927 127.93
## - texture_mean.c:logarea_mean.c                  1   98.470 130.47
## - texture_mean.c:logcompactness_mean.c           1   99.561 131.56
## - sqrtconcavity_mean.c:logarea_mean.c            1  100.230 132.23
## - texture_mean.c:smoothness_mean.c               1  108.924 140.92
## - smoothness_mean.c:sqrtconcavity_mean.c         1  110.498 142.50

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=122.63
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     sqrtconcave_points_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                    Df Deviance    AIC
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   87.729 121.73
## <none>                                                 90.628 122.63
## + texture_mean.c:sqrtconcave_points_mean.c         1   88.912 122.91
## + smoothness_mean.c:logcompactness_mean.c          1   88.934 122.93
## + symmetry_mean.c                                  1   89.333 123.33
## - sqrtconcave_points_mean.c:logarea_mean.c         1   93.490 123.49
## + smoothness_mean.c:logarea_mean.c                 1   89.506 123.51
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   89.517 123.52
## + logcompactness_mean.c:logarea_mean.c             1   90.436 124.44
## - texture_mean.c:sqrtconcavity_mean.c              1   94.638 124.64
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   96.600 126.60
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   96.627 126.63
## - texture_mean.c:logcompactness_mean.c             1  101.598 131.60
## - sqrtconcavity_mean.c:logarea_mean.c              1  101.694 131.69
## - texture_mean.c:logarea_mean.c                    1  101.740 131.74
## - texture_mean.c:smoothness_mean.c                 1  111.612 141.61
## - smoothness_mean.c:sqrtconcavity_mean.c           1  111.738 141.74

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=121.73
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     sqrtconcave_points_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c + sqrtconcavity_mean.c:sqrtconcave_points_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                  Df Deviance    AIC
## <none>                                                 87.729 121.73
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   90.628 122.63
## + texture_mean.c:sqrtconcave_points_mean.c         1   86.719 122.72
## + symmetry_mean.c                                  1   86.900 122.90
## + smoothness_mean.c:logarea_mean.c                 1   86.944 122.94
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   87.405 123.41
## + smoothness_mean.c:logcompactness_mean.c          1   87.642 123.64
## + logcompactness_mean.c:logarea_mean.c             1   87.645 123.64
## - sqrtconcave_points_mean.c:logarea_mean.c         1   93.244 125.24
## - texture_mean.c:sqrtconcavity_mean.c              1   94.512 126.51
```

```
## - texture_mean.c:logarea_mean.c                    1   96.251 128.25
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   96.469 128.47
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   96.552 128.55
## - texture_mean.c:logcompactness_mean.c             1  100.972 132.97
## - sqrtconcavity_mean.c:logarea_mean.c              1  100.985 132.99
## - texture_mean.c:smoothness_mean.c                 1  107.055 139.06
## - smoothness_mean.c:sqrtconcavity_mean.c           1  111.371 143.37
```

```
summary(lm4)
```

```
##
## Call:
## glm(formula = diagnosis ~ texture_mean.c + smoothness_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c + sqrtconcavity_mean.c:sqrtconcave_points_mean.c,
##     family = binomial, data = wisconsin)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.3712  -0.0848  -0.0091   0.0002   3.6723
##
## Coefficients:
##                                                 Estimate Std. Error z value
## (Intercept)                                    3.028e-02  5.415e-01   0.056
## texture_mean.c                                 6.319e-01  1.235e-01   5.118
## smoothness_mean.c                              1.288e+02  6.236e+01   2.066
## sqrtconcavity_mean.c                           5.112e+01  1.276e+01   4.006
## sqrtconcave_points_mean.c                      5.799e+01  4.297e+01   1.349
## logcompactness_mean.c                         -7.684e+00  2.256e+00  -3.407
## logarea_mean.c                                 9.597e+00  2.392e+00   4.013
## texture_mean.c:smoothness_mean.c               4.827e+01  1.467e+01   3.290
## texture_mean.c:sqrtconcavity_mean.c            5.212e+00  2.128e+00   2.450
## texture_mean.c:logcompactness_mean.c          -1.650e+00  5.182e-01  -3.184
## texture_mean.c:logarea_mean.c                  1.307e+00  4.851e-01   2.693
## smoothness_mean.c:sqrtconcavity_mean.c         4.045e+03  1.176e+03   3.441
## smoothness_mean.c:sqrtconcave_points_mean.c   -9.822e+03  3.878e+03  -2.533
## sqrtconcavity_mean.c:logcompactness_mean.c    -5.896e+01  2.473e+01  -2.385
## sqrtconcavity_mean.c:logarea_mean.c            9.540e+01  3.055e+01   3.123
## sqrtconcave_points_mean.c:logarea_mean.c      -3.080e+02  1.388e+02  -2.220
## sqrtconcavity_mean.c:sqrtconcave_points_mean.c 6.967e+02  4.428e+02   1.573
##                                                Pr(>|z|)
## (Intercept)                                    0.955407
## texture_mean.c                                 3.08e-07 ***
## smoothness_mean.c                              0.038870 *
## sqrtconcavity_mean.c                           6.17e-05 ***
## sqrtconcave_points_mean.c                      0.177194
## logcompactness_mean.c                          0.000658 ***
## logarea_mean.c                                 6.00e-05 ***
## texture_mean.c:smoothness_mean.c               0.001003 **
## texture_mean.c:sqrtconcavity_mean.c            0.014305 *
## texture_mean.c:logcompactness_mean.c           0.001454 **
```

```
## texture_mean.c:logarea_mean.c                  0.007071 **
## smoothness_mean.c:sqrtconcavity_mean.c         0.000579 ***
## smoothness_mean.c:sqrtconcave_points_mean.c    0.011319 *
## sqrtconcavity_mean.c:logcompactness_mean.c     0.017100 *
## sqrtconcavity_mean.c:logarea_mean.c            0.001791 **
## sqrtconcave_points_mean.c:logarea_mean.c       0.026442 *
## sqrtconcavity_mean.c:sqrtconcave_points_mean.c 0.115656
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 751.440  on 568  degrees of freedom
## Residual deviance:  87.729  on 552  degrees of freedom
## AIC: 121.73
##
## Number of Fisher Scoring iterations: 11
```

Given that our model generated using the AIC criteria kept a relatively large number of predictors (6) and interaction effects (10), we will run another step wise regression using BIC criteria which is more restrictive about which predictor variables are retained and compare the outputs

BIC

```r
lm5 = step(lm3, direction = "both", k = log(lm3$rank + lm3$df.residual))
```

```
## Start:  AIC=265.91
## diagnosis ~ (texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c)^2

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                Df Deviance    AIC
## - symmetry_mean.c:logarea_mean.c                1   81.963 259.59
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.001 259.63
## - logcompactness_mean.c:logarea_mean.c          1   82.002 259.63
## - smoothness_mean.c:symmetry_mean.c             1   82.011 259.64
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.036 259.66
## - symmetry_mean.c:logcompactness_mean.c         1   82.061 259.69
## - symmetry_mean.c:sqrtconcavity_mean.c          1   82.214 259.84
## - smoothness_mean.c:logcompactness_mean.c       1   82.402 260.03
## - texture_mean.c:symmetry_mean.c                1   82.478 260.11
## - texture_mean.c:sqrtconcave_points_mean.c      1   82.581 260.21
## - symmetry_mean.c:sqrtconcave_points_mean.c     1   82.620 260.25
## - smoothness_mean.c:logarea_mean.c              1   82.992 260.62
## - sqrtconcave_points_mean.c:logarea_mean.c      1   83.897 261.53
## - sqrtconcavity_mean.c:logcompactness_mean.c    1   84.487 262.12
## - texture_mean.c:sqrtconcavity_mean.c           1   84.509 262.14
## - sqrtconcavity_mean.c:logarea_mean.c           1   85.317 262.95
## - texture_mean.c:logcompactness_mean.c          1   87.013 264.64
## - smoothness_mean.c:sqrtconcave_points_mean.c   1   87.419 265.05
## <none>                                             81.934 265.91
## - texture_mean.c:logarea_mean.c                 1   89.449 267.08
## - texture_mean.c:smoothness_mean.c              1   91.005 268.63
## - smoothness_mean.c:sqrtconcavity_mean.c        1   97.910 275.54

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=259.59
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:symmetry_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcavity_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + symmetry_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
```

```
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c + logcompactness_mean.c:logarea_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                     Df Deviance    AIC
## - logcompactness_mean.c:logarea_mean.c               1   82.013 253.30
## - smoothness_mean.c:symmetry_mean.c                  1   82.015 253.30
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.029 253.31
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.059 253.34
## - symmetry_mean.c:logcompactness_mean.c            1   82.090 253.38
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.220 253.50
## - smoothness_mean.c:logcompactness_mean.c          1   82.428 253.71
```

```
## - texture_mean.c:symmetry_mean.c                   1   82.541 253.83
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.619 253.90
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   82.625 253.91
## - smoothness_mean.c:logarea_mean.c                 1   83.011 254.30
## - sqrtconcave_points_mean.c:logarea_mean.c         1   83.908 255.19
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.495 255.78
## - texture_mean.c:sqrtconcavity_mean.c              1   84.509 255.79
## - sqrtconcavity_mean.c:logarea_mean.c              1   85.350 256.63
## - texture_mean.c:logcompactness_mean.c             1   87.018 258.30
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   87.420 258.70
## <none>                                                 81.963 259.59
## - texture_mean.c:logarea_mean.c                    1   89.489 260.77
## - texture_mean.c:smoothness_mean.c                 1   91.018 262.30
## + symmetry_mean.c:logarea_mean.c                   1   81.934 265.91
## - smoothness_mean.c:sqrtconcavity_mean.c           1   98.274 269.56
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=253.3
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:symmetry_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcavity_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + symmetry_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                Df Deviance    AIC
## - smoothness_mean.c:symmetry_mean.c             1   82.057 247.00
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c  1   82.071 247.01
## - symmetry_mean.c:logcompactness_mean.c         1   82.105 247.05
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.166 247.11
## - symmetry_mean.c:sqrtconcavity_mean.c          1   82.223 247.16
## - texture_mean.c:symmetry_mean.c                1   82.565 247.51
## - texture_mean.c:sqrtconcave_points_mean.c      1   82.651 247.59
## - symmetry_mean.c:sqrtconcave_points_mean.c     1   82.664 247.60
## - smoothness_mean.c:logcompactness_mean.c       1   82.812 247.75
## - smoothness_mean.c:logarea_mean.c              1   83.049 247.99
## - sqrtconcave_points_mean.c:logarea_mean.c      1   83.948 248.89
## - sqrtconcavity_mean.c:logcompactness_mean.c    1   84.500 249.44
## - texture_mean.c:sqrtconcavity_mean.c           1   84.513 249.45
## - texture_mean.c:logcompactness_mean.c          1   87.038 251.98
## - sqrtconcavity_mean.c:logarea_mean.c           1   87.197 252.14
## - smoothness_mean.c:sqrtconcave_points_mean.c   1   87.542 252.48
## <none>                                             82.013 253.30
## - texture_mean.c:logarea_mean.c                 1   89.556 254.50
## - texture_mean.c:smoothness_mean.c              1   91.080 256.02
## + logcompactness_mean.c:logarea_mean.c          1   81.963 259.59
## + symmetry_mean.c:logarea_mean.c                1   82.002 259.63
## - smoothness_mean.c:sqrtconcavity_mean.c        1   98.277 263.22

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=247
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
```

```
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     symmetry_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                 Df Deviance    AIC
## - sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.090 240.69
## - symmetry_mean.c:logcompactness_mean.c            1   82.110 240.71
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.232 240.83
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.296 240.89
## - texture_mean.c:symmetry_mean.c                   1   82.598 241.19
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.682 241.28
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   82.690 241.29
## - smoothness_mean.c:logarea_mean.c                 1   83.091 241.69
## - smoothness_mean.c:logcompactness_mean.c          1   83.118 241.72
## - sqrtconcave_points_mean.c:logarea_mean.c         1   84.112 242.71
## - texture_mean.c:sqrtconcavity_mean.c              1   84.613 243.21
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.861 243.46
## - texture_mean.c:logcompactness_mean.c             1   87.319 245.92
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   88.173 246.77
## <none>                                                 82.057 247.00
## - sqrtconcavity_mean.c:logarea_mean.c              1   88.464 247.06
## - texture_mean.c:logarea_mean.c                    1   89.685 248.28
## - texture_mean.c:smoothness_mean.c                 1   91.176 249.77
## + smoothness_mean.c:symmetry_mean.c                1   82.013 253.30
## + logcompactness_mean.c:logarea_mean.c             1   82.015 253.30
## + symmetry_mean.c:logarea_mean.c                   1   82.057 253.34
## - smoothness_mean.c:sqrtconcavity_mean.c           1  100.635 259.23
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=240.69
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     symmetry_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                     Df Deviance    AIC
## - symmetry_mean.c:logcompactness_mean.c              1   82.122 234.38
## - symmetry_mean.c:sqrtconcavity_mean.c               1   82.237 234.49
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.595 234.85
## - texture_mean.c:symmetry_mean.c                     1   82.662 234.92
## - symmetry_mean.c:sqrtconcave_points_mean.c          1   82.731 234.98
## - texture_mean.c:sqrtconcave_points_mean.c           1   82.742 235.00
## - smoothness_mean.c:logarea_mean.c                   1   83.161 235.41
## - smoothness_mean.c:logcompactness_mean.c            1   83.883 236.14
## - sqrtconcave_points_mean.c:logarea_mean.c           1   84.113 236.37
## - texture_mean.c:sqrtconcavity_mean.c                1   84.743 237.00
## - sqrtconcavity_mean.c:logcompactness_mean.c         1   84.880 237.13
## - texture_mean.c:logcompactness_mean.c               1   87.320 239.57
## - smoothness_mean.c:sqrtconcave_points_mean.c        1   88.205 240.46
## <none>                                                   82.090 240.69
## - sqrtconcavity_mean.c:logarea_mean.c                1   89.649 241.90
## - texture_mean.c:logarea_mean.c                      1   89.792 242.04
## - texture_mean.c:smoothness_mean.c                   1   91.400 243.65
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.057 247.00
## + smoothness_mean.c:symmetry_mean.c                  1   82.071 247.01
## + logcompactness_mean.c:logarea_mean.c               1   82.076 247.02
## + symmetry_mean.c:logarea_mean.c                     1   82.087 247.03
## - smoothness_mean.c:sqrtconcavity_mean.c             1  102.307 254.56

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=234.37
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
```

```
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcavity_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##                                                   Df Deviance    AIC
## - symmetry_mean.c:sqrtconcavity_mean.c             1   82.237 228.15
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   82.611 228.52
## - texture_mean.c:sqrtconcave_points_mean.c         1   82.784 228.69
## - texture_mean.c:symmetry_mean.c                   1   82.797 228.71
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   83.007 228.92
## - smoothness_mean.c:logarea_mean.c                 1   83.233 229.14
## - sqrtconcave_points_mean.c:logarea_mean.c         1   84.297 230.21
## - smoothness_mean.c:logcompactness_mean.c          1   84.402 230.31
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   84.893 230.80
## - texture_mean.c:sqrtconcavity_mean.c              1   85.032 230.94
## - texture_mean.c:logcompactness_mean.c             1   88.438 234.35
## <none>                                                 82.122 234.38
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   89.510 235.42
## - texture_mean.c:logarea_mean.c                    1   89.807 235.72
## - sqrtconcavity_mean.c:logarea_mean.c              1   90.698 236.61
## - texture_mean.c:smoothness_mean.c                 1   91.629 237.54
## + symmetry_mean.c:logcompactness_mean.c            1   82.090 240.69
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.110 240.71
## + symmetry_mean.c:logarea_mean.c                   1   82.113 240.71
## + logcompactness_mean.c:logarea_mean.c             1   82.114 240.71
## + smoothness_mean.c:symmetry_mean.c                1   82.119 240.72
## - smoothness_mean.c:sqrtconcavity_mean.c           1  102.310 248.22
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=228.15
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:symmetry_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:sqrtconcave_points_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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##                                                    Df Deviance    AIC
## - texture_mean.c:symmetry_mean.c                    1   82.865 222.43
## - texture_mean.c:sqrtconcave_points_mean.c          1   82.893 222.46
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.028 222.59
## - smoothness_mean.c:logarea_mean.c                  1   83.452 223.02
## - symmetry_mean.c:sqrtconcave_points_mean.c         1   83.764 223.33
## - smoothness_mean.c:logcompactness_mean.c           1   84.411 223.98
## - texture_mean.c:sqrtconcavity_mean.c               1   85.445 225.01
## - sqrtconcave_points_mean.c:logarea_mean.c          1   85.491 225.06
## - sqrtconcavity_mean.c:logcompactness_mean.c        1   87.298 226.86
## <none>                                                  82.237 228.15
## - texture_mean.c:logcompactness_mean.c              1   88.669 228.23
## - texture_mean.c:logarea_mean.c                     1   89.830 229.40
## - smoothness_mean.c:sqrtconcave_points_mean.c       1   89.844 229.41
## - texture_mean.c:smoothness_mean.c                  1   91.631 231.20
## + symmetry_mean.c:sqrtconcavity_mean.c              1   82.122 234.38
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c    1   82.233 234.49
## + smoothness_mean.c:symmetry_mean.c                 1   82.233 234.49
## + logcompactness_mean.c:logarea_mean.c              1   82.236 234.49
## + symmetry_mean.c:logarea_mean.c                    1   82.236 234.49
## + symmetry_mean.c:logcompactness_mean.c             1   82.237 234.49
## - sqrtconcavity_mean.c:logarea_mean.c               1   96.411 235.98
## - smoothness_mean.c:sqrtconcavity_mean.c            1  104.483 244.05

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=222.43
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
```

```
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:sqrtconcave_points_mean.c + texture_mean.c:logcompactness_mean.c +
##     texture_mean.c:logarea_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     smoothness_mean.c:sqrtconcave_points_mean.c + smoothness_mean.c:logcompactness_mean.c +
##     smoothness_mean.c:logarea_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logcompactness_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                  Df Deviance    AIC
## - texture_mean.c:sqrtconcave_points_mean.c        1   83.829 217.05
```

```
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.895 217.12
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   84.195 217.42
## - smoothness_mean.c:logarea_mean.c                 1   84.456 217.68
## - smoothness_mean.c:logcompactness_mean.c          1   85.327 218.55
## - sqrtconcave_points_mean.c:logarea_mean.c         1   86.472 219.69
## - texture_mean.c:sqrtconcavity_mean.c              1   88.158 221.38
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   88.650 221.87
## - texture_mean.c:logcompactness_mean.c             1   88.913 222.13
## <none>                                                 82.865 222.43
## - texture_mean.c:logarea_mean.c                    1   90.112 223.33
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   91.215 224.44
## - texture_mean.c:smoothness_mean.c                 1   94.619 227.84
## + texture_mean.c:symmetry_mean.c                   1   82.237 228.15
## + symmetry_mean.c:sqrtconcavity_mean.c             1   82.797 228.71
## + symmetry_mean.c:logarea_mean.c                   1   82.816 228.73
## + symmetry_mean.c:logcompactness_mean.c            1   82.829 228.74
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   82.853 228.76
## + smoothness_mean.c:symmetry_mean.c                1   82.860 228.77
## + logcompactness_mean.c:logarea_mean.c             1   82.861 228.77
## - sqrtconcavity_mean.c:logarea_mean.c              1   97.787 231.01
## - smoothness_mean.c:sqrtconcavity_mean.c           1  105.900 239.12
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##
## Step:  AIC=217.05
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logcompactness_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                   Df Deviance    AIC
## - sqrtconcave_points_mean.c:logcompactness_mean.c  1   84.681 211.56
## - symmetry_mean.c:sqrtconcave_points_mean.c        1   84.952 211.83
## - smoothness_mean.c:logarea_mean.c                 1   85.401 212.28
## - sqrtconcave_points_mean.c:logarea_mean.c         1   86.478 213.35
## - smoothness_mean.c:logcompactness_mean.c          1   86.590 213.47
## - texture_mean.c:sqrtconcavity_mean.c              1   88.170 215.05
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   89.210 216.09
## <none>                                                 83.829 217.05
## - texture_mean.c:logarea_mean.c                    1   90.649 217.53
## - texture_mean.c:logcompactness_mean.c             1   90.816 217.69
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   91.259 218.14
## + texture_mean.c:sqrtconcave_points_mean.c         1   82.865 222.43
## + texture_mean.c:symmetry_mean.c                   1   82.893 222.46
## - texture_mean.c:smoothness_mean.c                 1   95.845 222.72
## + symmetry_mean.c:logarea_mean.c                   1   83.737 223.30
## + symmetry_mean.c:sqrtconcavity_mean.c             1   83.741 223.31
## + symmetry_mean.c:logcompactness_mean.c            1   83.785 223.35
## + logcompactness_mean.c:logarea_mean.c             1   83.809 223.37
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   83.809 223.37
## + smoothness_mean.c:symmetry_mean.c                1   83.818 223.38
## - sqrtconcavity_mean.c:logarea_mean.c              1   97.891 224.77
## - smoothness_mean.c:sqrtconcavity_mean.c           1  106.100 232.98

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=211.56
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
```

```
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + smoothness_mean.c:logarea_mean.c +
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logarea_mean.c
```

```
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```

```
##                                                  Df Deviance    AIC
## - smoothness_mean.c:logarea_mean.c                1   86.393 206.93
## - symmetry_mean.c:sqrtconcave_points_mean.c       1   86.415 206.95
## - sqrtconcave_points_mean.c:logarea_mean.c        1   86.543 207.08
```

```
## - smoothness_mean.c:logcompactness_mean.c         1   86.671 207.21
## - texture_mean.c:sqrtconcavity_mean.c             1   89.842 210.38
## - sqrtconcavity_mean.c:logcompactness_mean.c      1   90.346 210.88
## <none>                                                84.681 211.56
## - smoothness_mean.c:sqrtconcave_points_mean.c     1   91.371 211.91
## - texture_mean.c:logarea_mean.c                   1   93.086 213.62
## - texture_mean.c:logcompactness_mean.c            1   95.507 216.04
## + texture_mean.c:symmetry_mean.c                  1   83.523 216.75
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   83.829 217.05
## + texture_mean.c:sqrtconcave_points_mean.c        1   83.895 217.12
## + symmetry_mean.c:sqrtconcavity_mean.c            1   84.333 217.55
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c  1   84.389 217.61
## + smoothness_mean.c:symmetry_mean.c               1   84.638 217.86
## + logcompactness_mean.c:logarea_mean.c            1   84.679 217.90
## + symmetry_mean.c:logarea_mean.c                  1   84.680 217.90
## + symmetry_mean.c:logcompactness_mean.c           1   84.680 217.90
## - sqrtconcavity_mean.c:logarea_mean.c             1   98.398 218.93
## - texture_mean.c:smoothness_mean.c                1  103.921 224.46
## - smoothness_mean.c:sqrtconcavity_mean.c          1  106.847 227.38
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=206.93
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     smoothness_mean.c:logcompactness_mean.c + symmetry_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                 Df Deviance    AIC
## - smoothness_mean.c:logcompactness_mean.c         1   87.590 201.78
## - symmetry_mean.c:sqrtconcave_points_mean.c       1   87.936 202.13
## - sqrtconcave_points_mean.c:logarea_mean.c        1   89.747 203.94
## - texture_mean.c:sqrtconcavity_mean.c             1   92.066 206.26
## - sqrtconcavity_mean.c:logcompactness_mean.c      1   92.120 206.31
## <none>                                                86.393 206.93
## - smoothness_mean.c:sqrtconcave_points_mean.c     1   93.333 207.52
## - texture_mean.c:logarea_mean.c                   1   94.615 208.81
## + smoothness_mean.c:logarea_mean.c                1   84.681 211.56
## + texture_mean.c:symmetry_mean.c                  1   84.804 211.68
## - texture_mean.c:logcompactness_mean.c            1   97.614 211.80
## + sqrtconcave_points_mean.c:logcompactness_mean.c 1   85.401 212.28
## + texture_mean.c:sqrtconcave_points_mean.c        1   85.537 212.41
## + symmetry_mean.c:sqrtconcavity_mean.c            1   85.906 212.78
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c  1   85.922 212.80
## + logcompactness_mean.c:logarea_mean.c            1   86.000 212.88
## - sqrtconcavity_mean.c:logarea_mean.c             1   98.928 213.12
## + symmetry_mean.c:logarea_mean.c                  1   86.365 213.24
## + symmetry_mean.c:logcompactness_mean.c           1   86.384 213.26
## + smoothness_mean.c:symmetry_mean.c               1   86.390 213.27
## - texture_mean.c:smoothness_mean.c                1  104.933 219.12
## - smoothness_mean.c:sqrtconcavity_mean.c          1  107.124 221.31

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=201.78
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
```

```
##     symmetry_mean.c:sqrtconcave_points_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c + sqrtconcave_points_mean.c:logarea_mean.c

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                    Df Deviance    AIC
## - symmetry_mean.c:sqrtconcave_points_mean.c         1   89.333 197.18
## - sqrtconcave_points_mean.c:logarea_mean.c          1   90.458 198.30
## - texture_mean.c:sqrtconcavity_mean.c               1   92.066 199.91
## <none>                                                  87.590 201.78
## - smoothness_mean.c:sqrtconcave_points_mean.c       1   95.391 203.24
## - sqrtconcavity_mean.c:logcompactness_mean.c        1   95.867 203.71
## - texture_mean.c:logarea_mean.c                     1   96.860 204.71
```

```
## - texture_mean.c:logcompactness_mean.c            1   97.656 205.50
## + texture_mean.c:symmetry_mean.c                  1   85.965 206.50
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   86.043 206.58
## + smoothness_mean.c:logcompactness_mean.c          1   86.393 206.93
## + texture_mean.c:sqrtconcave_points_mean.c         1   86.553 207.09
## - sqrtconcavity_mean.c:logarea_mean.c              1   99.340 207.19
## + smoothness_mean.c:logarea_mean.c                 1   86.671 207.21
## + smoothness_mean.c:symmetry_mean.c                1   87.364 207.90
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   87.378 207.91
## + symmetry_mean.c:logcompactness_mean.c            1   87.467 208.00
## + symmetry_mean.c:sqrtconcavity_mean.c             1   87.518 208.05
## + logcompactness_mean.c:logarea_mean.c             1   87.541 208.07
## + symmetry_mean.c:logarea_mean.c                   1   87.583 208.12
## - texture_mean.c:smoothness_mean.c                 1  106.059 213.91
## - smoothness_mean.c:sqrtconcavity_mean.c           1  109.846 217.69
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=197.18
## diagnosis ~ texture_mean.c + smoothness_mean.c + symmetry_mean.c +
##     sqrtconcavity_mean.c + sqrtconcave_points_mean.c + logcompactness_mean.c +
##     logarea_mean.c + texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                 Df Deviance    AIC
## - symmetry_mean.c                                1   90.628 192.13
## - sqrtconcave_points_mean.c:logarea_mean.c       1   92.146 193.65
## - texture_mean.c:sqrtconcavity_mean.c            1   92.839 194.34
## - smoothness_mean.c:sqrtconcave_points_mean.c    1   95.409 196.91
## <none>                                               89.333 197.18
## - sqrtconcavity_mean.c:logcompactness_mean.c     1   95.927 197.43
## - texture_mean.c:logarea_mean.c                  1   98.470 199.97
## - texture_mean.c:logcompactness_mean.c           1   99.561 201.06
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c 1   86.900 201.09
## - sqrtconcavity_mean.c:logarea_mean.c            1  100.230 201.73
## + symmetry_mean.c:sqrtconcave_points_mean.c      1   87.590 201.78
## + smoothness_mean.c:logcompactness_mean.c        1   87.936 202.13
## + texture_mean.c:sqrtconcave_points_mean.c       1   88.072 202.26
## + smoothness_mean.c:logarea_mean.c               1   88.303 202.49
## + sqrtconcave_points_mean.c:logcompactness_mean.c 1  88.463 202.65
## + symmetry_mean.c:sqrtconcavity_mean.c           1   88.473 202.66
## + texture_mean.c:symmetry_mean.c                 1   88.568 202.76
## + symmetry_mean.c:logcompactness_mean.c          1   88.689 202.88
## + logcompactness_mean.c:logarea_mean.c           1   89.091 203.28
## + smoothness_mean.c:symmetry_mean.c              1   89.233 203.42
## + symmetry_mean.c:logarea_mean.c                 1   89.304 203.49
## - texture_mean.c:smoothness_mean.c               1  108.924 210.43
## - smoothness_mean.c:sqrtconcavity_mean.c         1  110.498 212.00

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=192.13
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     sqrtconcave_points_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c +
##     sqrtconcave_points_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
##                                                    Df Deviance    AIC
## - sqrtconcave_points_mean.c:logarea_mean.c          1   93.490 188.65
## - texture_mean.c:sqrtconcavity_mean.c               1   94.638 189.80
## - sqrtconcavity_mean.c:logcompactness_mean.c        1   96.600 191.76
## - smoothness_mean.c:sqrtconcave_points_mean.c       1   96.627 191.78
## <none>                                                  90.628 192.13
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c    1   87.729 195.57
## - texture_mean.c:logcompactness_mean.c              1  101.598 196.76
## + texture_mean.c:sqrtconcave_points_mean.c          1   88.912 196.76
## + smoothness_mean.c:logcompactness_mean.c           1   88.934 196.78
## - sqrtconcavity_mean.c:logarea_mean.c               1  101.694 196.85
## - texture_mean.c:logarea_mean.c                     1  101.740 196.90
## + symmetry_mean.c                                   1   89.333 197.18
## + smoothness_mean.c:logarea_mean.c                  1   89.506 197.35
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   89.517 197.36
## + logcompactness_mean.c:logarea_mean.c              1   90.436 198.28
## - texture_mean.c:smoothness_mean.c                  1  111.612 206.77
## - smoothness_mean.c:sqrtconcavity_mean.c            1  111.738 206.90

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=188.65
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     sqrtconcave_points_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + smoothness_mean.c:sqrtconcave_points_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                                   Df Deviance    AIC
## - smoothness_mean.c:sqrtconcave_points_mean.c      1   97.533 186.35
## <none>                                                 93.490 188.65
## - sqrtconcavity_mean.c:logcompactness_mean.c       1   99.911 188.73
## - texture_mean.c:sqrtconcavity_mean.c              1  100.058 188.87
## - sqrtconcavity_mean.c:logarea_mean.c              1  103.116 191.93
## + sqrtconcave_points_mean.c:logarea_mean.c         1   90.628 192.13
## + smoothness_mean.c:logarea_mean.c                 1   91.433 192.94
## + logcompactness_mean.c:logarea_mean.c             1   92.088 193.59
## + symmetry_mean.c                                  1   92.146 193.65
## + smoothness_mean.c:logcompactness_mean.c          1   92.606 194.11
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   93.244 194.75
```

```
## + texture_mean.c:sqrtconcave_points_mean.c         1   93.409 194.91
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   93.431 194.93
## - texture_mean.c:logcompactness_mean.c             1  106.564 195.38
## - texture_mean.c:logarea_mean.c                    1  109.065 197.88
## - smoothness_mean.c:sqrtconcavity_mean.c           1  111.763 200.58
## - texture_mean.c:smoothness_mean.c                 1  114.985 203.80

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=186.35
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     sqrtconcave_points_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c + sqrtconcavity_mean.c:logcompactness_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##                                                   Df Deviance    AIC
## - sqrtconcave_points_mean.c                        1   98.024 180.50
```

```
## - sqrtconcavity_mean.c:logcompactness_mean.c       1  101.226 183.70
## - sqrtconcavity_mean.c:logarea_mean.c              1  103.435 185.91
## <none>                                                 97.533 186.35
## - texture_mean.c:sqrtconcavity_mean.c              1  104.280 186.75
## + smoothness_mean.c:sqrtconcave_points_mean.c      1   93.490 188.65
## + smoothness_mean.c:logarea_mean.c                 1   95.509 190.67
## + smoothness_mean.c:logcompactness_mean.c          1   95.520 190.68
## + symmetry_mean.c                                  1   96.234 191.39
## + sqrtconcave_points_mean.c:logcompactness_mean.c  1   96.250 191.41
## + logcompactness_mean.c:logarea_mean.c             1   96.540 191.70
## + sqrtconcave_points_mean.c:logarea_mean.c         1   96.627 191.78
## + texture_mean.c:sqrtconcave_points_mean.c         1   97.531 192.69
## + sqrtconcavity_mean.c:sqrtconcave_points_mean.c   1   97.531 192.69
## - texture_mean.c:logcompactness_mean.c             1  111.611 194.08
## - texture_mean.c:logarea_mean.c                    1  113.852 196.32
## - smoothness_mean.c:sqrtconcavity_mean.c           1  118.693 201.16
## - texture_mean.c:smoothness_mean.c                 1  129.317 211.79
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##
## Step:  AIC=180.49
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     logcompactness_mean.c + logarea_mean.c + texture_mean.c:smoothness_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:logcompactness_mean.c +
##     texture_mean.c:logarea_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     sqrtconcavity_mean.c:logcompactness_mean.c + sqrtconcavity_mean.c:logarea_mean.c
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
##                                              Df Deviance    AIC
## - sqrtconcavity_mean.c:logcompactness_mean.c  1  101.384 177.51
```

```
## <none>                                          98.024 180.50
## - texture_mean.c:sqrtconcavity_mean.c         1  104.401 180.53
## - sqrtconcavity_mean.c:logarea_mean.c         1  105.909 182.04
## + smoothness_mean.c:logcompactness_mean.c     1   95.775 184.59
## + smoothness_mean.c:logarea_mean.c            1   96.312 185.13
## + symmetry_mean.c                             1   96.833 185.65
## + logcompactness_mean.c:logarea_mean.c        1   97.201 186.01
## + sqrtconcave_points_mean.c                   1   97.533 186.35
## - texture_mean.c:logcompactness_mean.c        1  111.792 187.92
## - texture_mean.c:logarea_mean.c               1  114.302 190.43
## - smoothness_mean.c:sqrtconcavity_mean.c      1  119.984 196.11
## - texture_mean.c:smoothness_mean.c            1  130.404 206.53

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=177.51
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     logcompactness_mean.c + logarea_mean.c + texture_mean.c:smoothness_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:logcompactness_mean.c +
##     texture_mean.c:logarea_mean.c + smoothness_mean.c:sqrtconcavity_mean.c +
##     sqrtconcavity_mean.c:logarea_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##                                              Df Deviance    AIC
## - sqrtconcavity_mean.c:logarea_mean.c         1  107.179 176.96
## <none>                                           101.384 177.51
## - texture_mean.c:sqrtconcavity_mean.c         1  108.996 178.78
## + sqrtconcavity_mean.c:logcompactness_mean.c  1   98.024 180.50
## + smoothness_mean.c:logcompactness_mean.c     1   98.521 180.99
## + smoothness_mean.c:logarea_mean.c            1   99.667 182.14
```

```
## + logcompactness_mean.c:logarea_mean.c        1   99.819 182.29
## + symmetry_mean.c                             1  100.804 183.28
## + sqrtconcave_points_mean.c                   1  101.226 183.70
## - texture_mean.c:logcompactness_mean.c        1  114.225 184.01
## - texture_mean.c:logarea_mean.c               1  115.519 185.30
## - smoothness_mean.c:sqrtconcavity_mean.c      1  120.104 189.89
## - texture_mean.c:smoothness_mean.c            1  130.775 200.56

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=176.96
## diagnosis ~ texture_mean.c + smoothness_mean.c + sqrtconcavity_mean.c +
##     logcompactness_mean.c + logarea_mean.c + texture_mean.c:smoothness_mean.c +
##     texture_mean.c:sqrtconcavity_mean.c + texture_mean.c:logcompactness_mean.c +
##     texture_mean.c:logarea_mean.c + smoothness_mean.c:sqrtconcavity_mean.c

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

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## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##                                              Df Deviance    AIC
## <none>                                            107.18 176.96
## + sqrtconcavity_mean.c:logarea_mean.c         1   101.38 177.51
## - texture_mean.c:logarea_mean.c               1   116.67 180.11
## + sqrtconcave_points_mean.c                   1   105.67 181.79
## + smoothness_mean.c:logcompactness_mean.c     1   105.84 181.97
## + sqrtconcavity_mean.c:logcompactness_mean.c  1   105.91 182.04
## + logcompactness_mean.c:logarea_mean.c        1   106.25 182.37
## + symmetry_mean.c                             1   106.86 182.99
## - texture_mean.c:sqrtconcavity_mean.c         1   119.62 183.06
## + smoothness_mean.c:logarea_mean.c            1   107.16 183.28
## - smoothness_mean.c:sqrtconcavity_mean.c      1   121.20 184.64
## - texture_mean.c:logcompactness_mean.c        1   122.14 185.57
```

```
## - texture_mean.c:smoothness_mean.c            1   132.65 196.09
```

```
summary(lm5)
```

```
##
## Call:
## glm(formula = diagnosis ~ texture_mean.c + smoothness_mean.c +
##     sqrtconcavity_mean.c + logcompactness_mean.c + logarea_mean.c +
##     texture_mean.c:smoothness_mean.c + texture_mean.c:sqrtconcavity_mean.c +
##     texture_mean.c:logcompactness_mean.c + texture_mean.c:logarea_mean.c +
##     smoothness_mean.c:sqrtconcavity_mean.c, family = binomial,
##     data = wisconsin)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.2121  -0.0999  -0.0137   0.0009   3.5626
##
## Coefficients:
##                                      Estimate Std. Error z value Pr(>|z|)
## (Intercept)                           -1.2176     0.3238  -3.760 0.000170 ***
## texture_mean.c                         0.5738     0.1047   5.481 4.23e-08 ***
## smoothness_mean.c                    206.4960    43.8422   4.710 2.48e-06 ***
## sqrtconcavity_mean.c                  29.9367     6.2486   4.791 1.66e-06 ***
## logcompactness_mean.c                 -4.1492     1.5654  -2.651 0.008035 **
## logarea_mean.c                        12.2830     1.8590   6.607 3.91e-11 ***
## texture_mean.c:smoothness_mean.c      41.2347     9.8465   4.188 2.82e-05 ***
## texture_mean.c:sqrtconcavity_mean.c    4.7171     1.4489   3.256 0.001131 **
## texture_mean.c:logcompactness_mean.c  -1.3355     0.3649  -3.660 0.000252 ***
## texture_mean.c:logarea_mean.c          1.0290     0.3774   2.727 0.006397 **
## smoothness_mean.c:sqrtconcavity_mean.c 967.4881   276.3854   3.501 0.000464 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 751.44  on 568  degrees of freedom
## Residual deviance: 107.18  on 558  degrees of freedom
## AIC: 129.18
##
## Number of Fisher Scoring iterations: 9
```

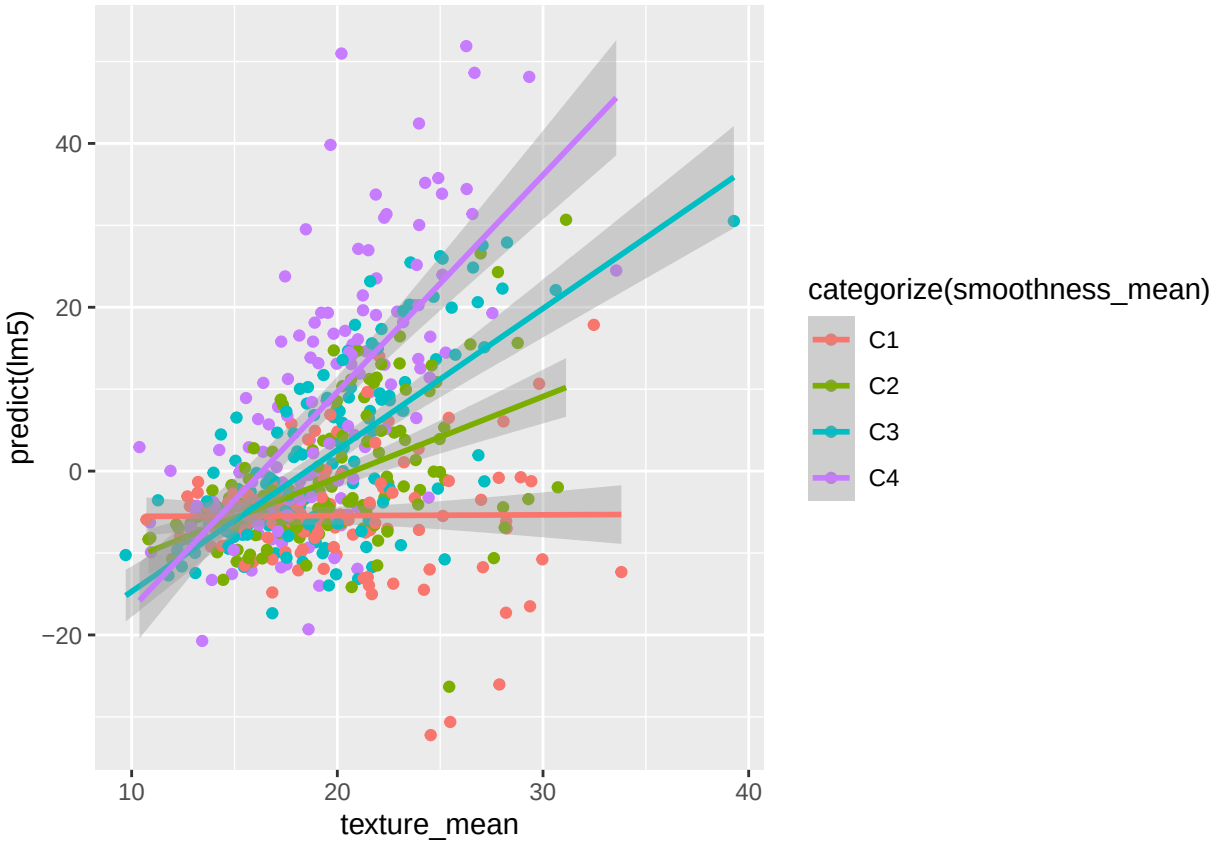
The BIC model kept mean texture, smoothness, sqrt concavity, log compactness, log area, and the interaction between texture and smoothness, sqrt concavity, log compactness, and log area as well as the interaction between smoothness and sqrt concavity. Overall, 5 predictors and 5 interactions, all of which were significant, were kept in the final model. Residual deviance (107.18 in BIC model and 87.729 AIC model) and AIC values (129.18 in BIC model and 121.73 in AIC model) are relatively similar between the BIC and the AIC models. This gives us confidence proceeding with the BIC model as our final model for simplicity's sake. The AIC of this model (129.18) is considerably smaller than the AIC of the full first order model (162.66) or the model generated from the step wise regression on the first order model (158.04).

Interaction plots

```
#categorize function
categorize = function (x, quantiles=(1:3)/4) {
```

```
  cutoffs = quantile (x, quantiles)
  n.cutoffs = length (cutoffs)
  result = rep ("C1", length (x))
  for (j in 1:n.cutoffs) {
    result [x > cutoffs [j]] = paste ("C", j+1, sep="")
  }
  return (result)
}
#Interaction plot between mean texture and mean smoothness
library (ggplot2)
qplot (texture_mean, predict (lm5), data= wisconsin, color=categorize (smoothness_mean)) +
  geom_smooth (method="lm")
```

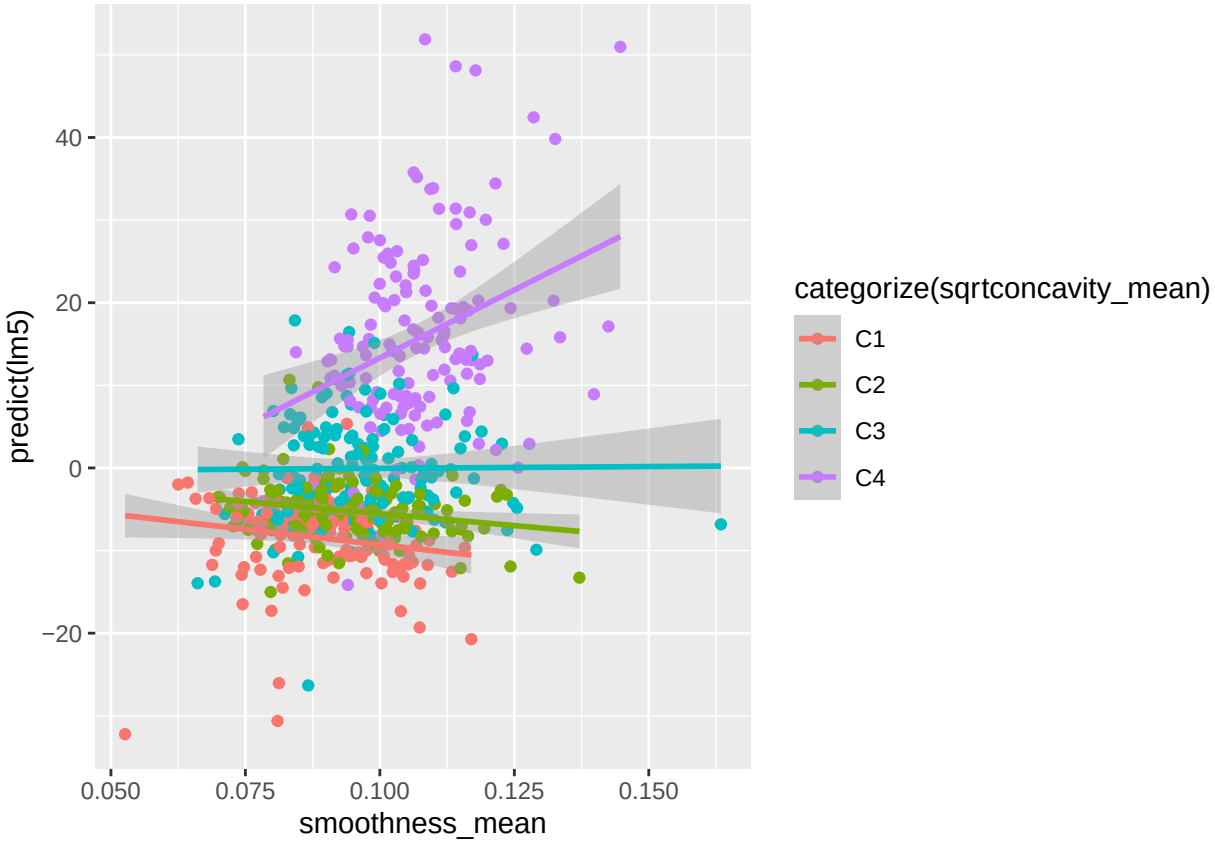
```
## `geom_smooth()` using formula 'y ~ x'
```



The interaction plot above shows that the relationship between the odds of a tumor being malignant and mean texture is stronger (steeper) for samples with higher mean smoothness values as opposed to lower smoothness values. This suggests that a sample's mean texture is more predictive of diagnosis (malignant vs benign) if on average it is more smooth.

```
# Interaction plot between mean smoothness and mean sqrt concavity
qplot (smoothness_mean, predict (lm5), data= wisconsin, color=categorize (sqrtconcavity_mean)) +
  geom_smooth (method="lm")
```

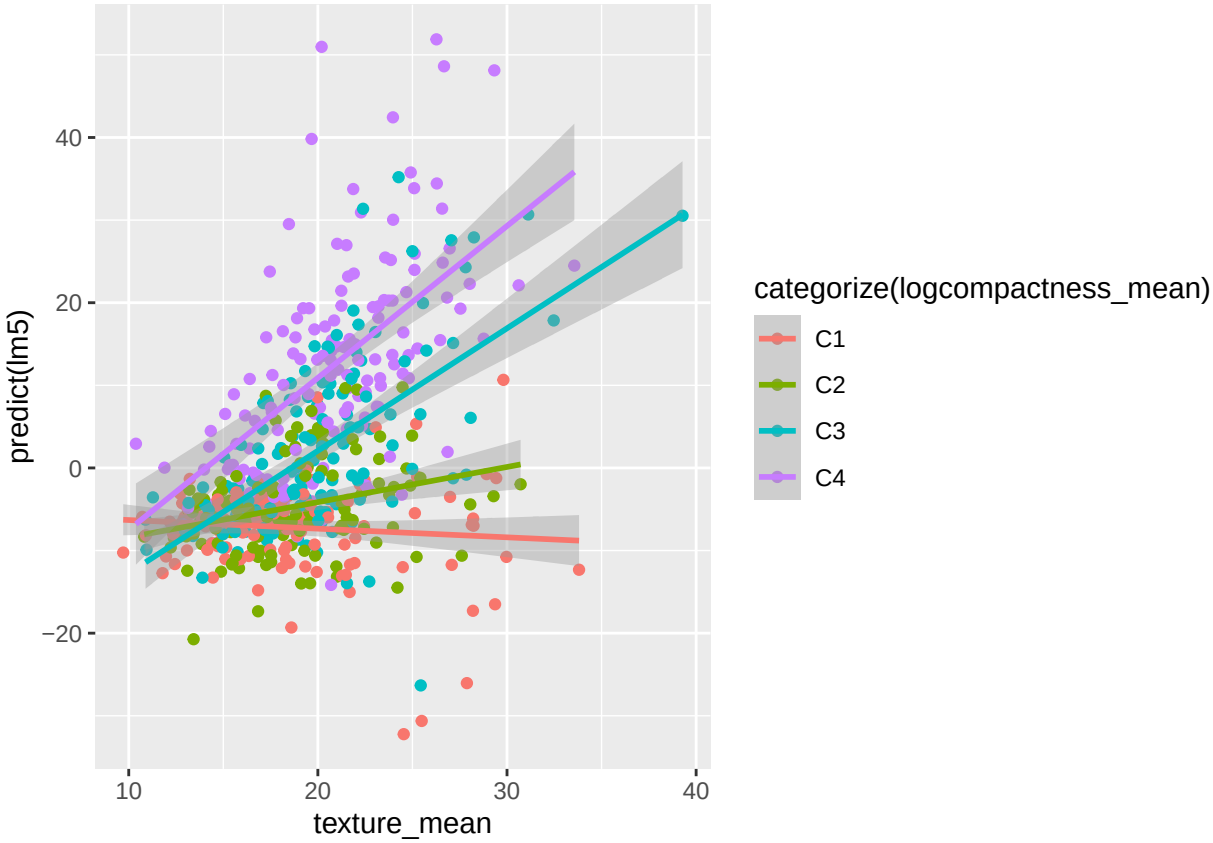
```
## `geom_smooth()` using formula 'y ~ x'
```



The interaction plot above shows that the relationship between mean smoothness and the odds of a tumor being malignant is minimal (close to zero) for cases in the lowest 75% of square root transformed mean concavity but strong for the cases with the highest square root transformed mean concavity. In other words, when mean square root transformed concavity is not high, mean smoothness is not very predictive of tumor diagnosis. However, when concavity is high, increasing mean smoothness is strongly associated with increased likelihood of a malignant tumor diagnosis.

```
# Interaction plot between mean texture and mean log compactness
qplot (texture_mean, predict (lm5), data= wisconsin, color=categorize (logcompactness_mean)) +
  geom_smooth (method="lm")
```

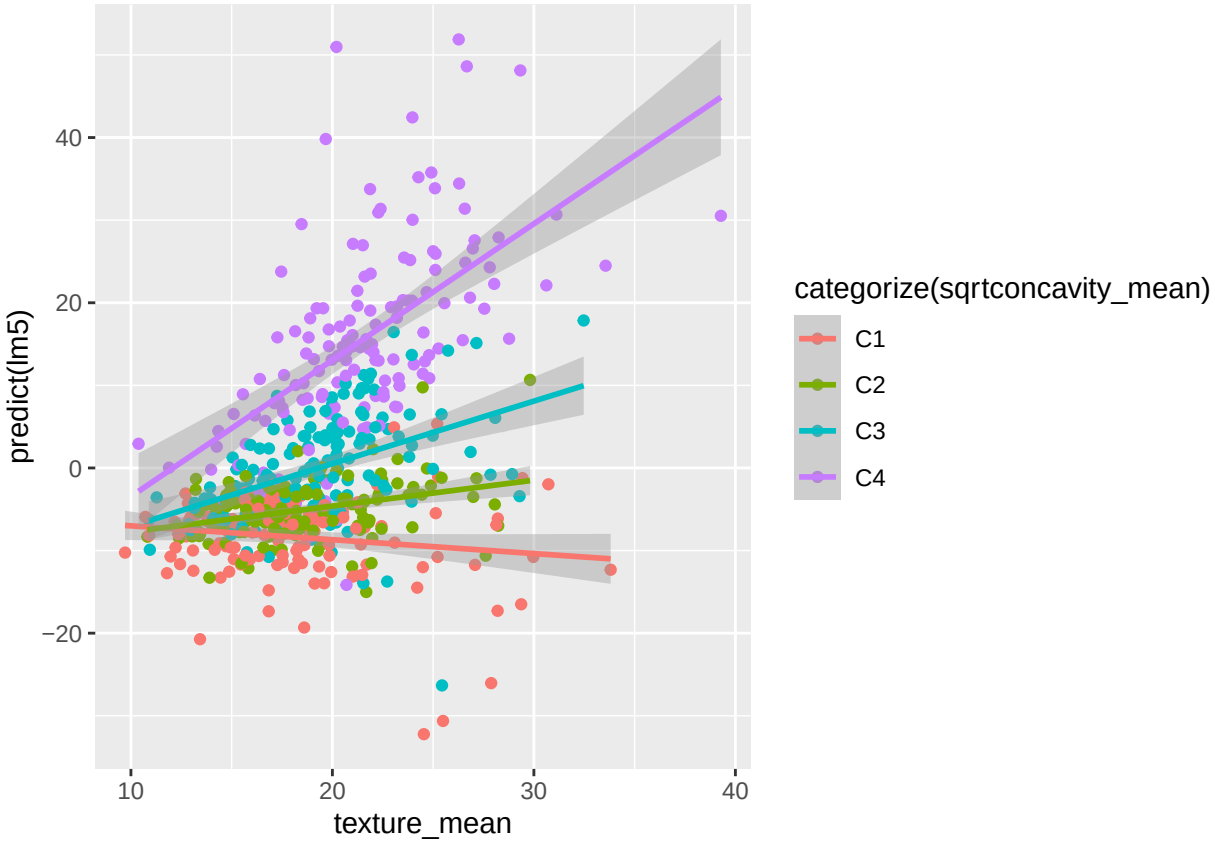
```
## `geom_smooth()` using formula 'y ~ x'
```



The interaction plot above shows that the relationship between the probability of a tumor being malignant and mean texture is stronger (steeper) for samples with higher mean log transformed compactness values as opposed to lower values. This suggests that a sample's mean texture is more predictive of tumor diagnosis if on average it is more compact.

```
# Interaction between mean texture and mean sqrt concavity
qplot (texture_mean, predict (lm5), data= wisconsin, color=categorize (sqrtconcavity_mean)) +
  geom_smooth (method="lm")
```

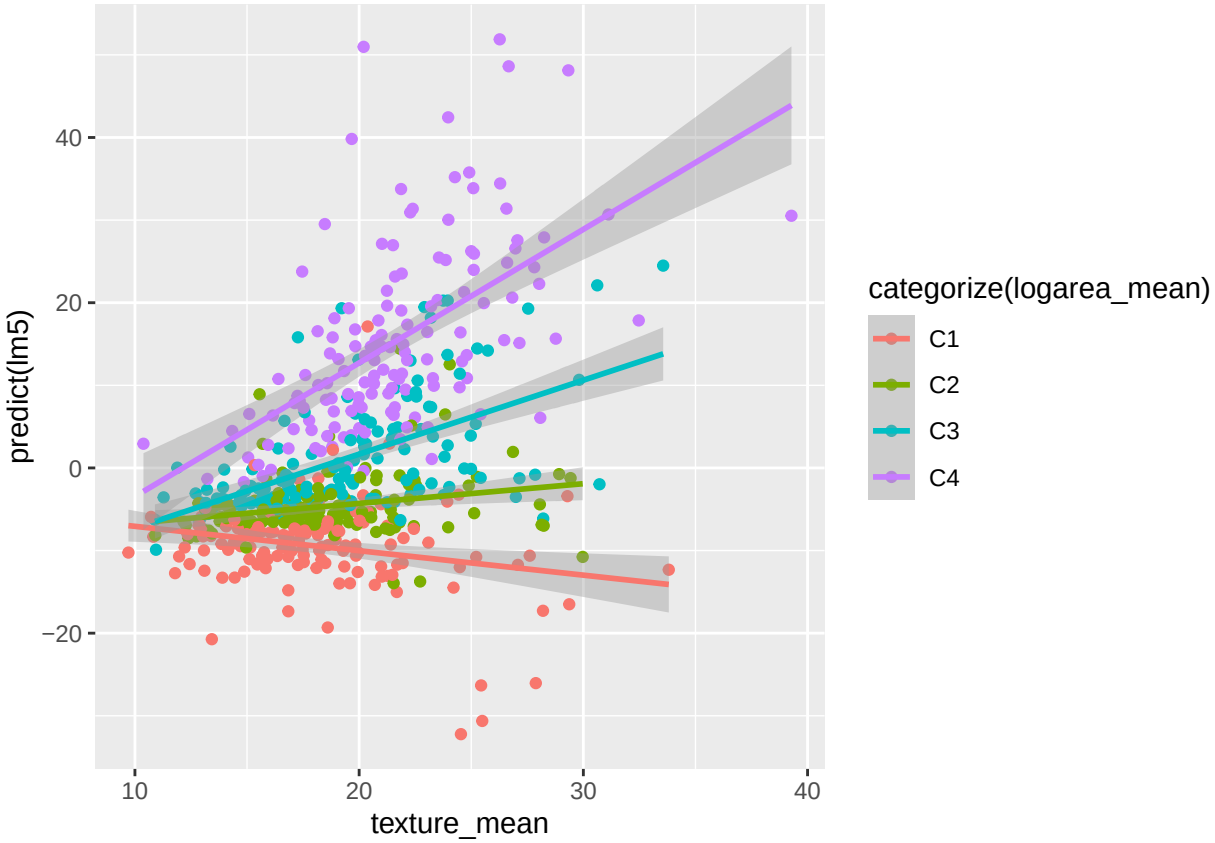
```
## `geom_smooth()` using formula 'y ~ x'
```



The interaction plot above shows that the relationship between the probability of a tumor being malignant and mean texture is stronger (steeper) for samples with higher mean square root transformed concavity values as opposed to lower values. This suggests that a sample's mean texture is more predictive of diagnosis (malignant vs benign) if on average it has greater concavity.

```
# Interaction between mean texture and mean log area
qplot (texture_mean, predict (lm5), data= wisconsin, color=categorize (logarea_mean)) +
  geom_smooth (method="lm")
```

```
## `geom_smooth()` using formula 'y ~ x'
```



The interaction plot above shows that for samples in the largest 50% of mean log area, the relationship between the probability of a tumor being malignant and mean texture is strong. Conversely, for samples with smaller mean log area values, the relationship between mean texture and the odds of a tumor being malignant is minimal. For cells with the smallest area, the relationship between odds of a malignant diagnosis and mean texture may become slightly negative which would suggest that in samples with low average cell area, increasing mean texture results in lower odds of a malignant diagnosis.

Final Model

All predictors in the final model are included in the significant interaction effects making interpretations of the individual coefficients less meaningful. Our qualitative interpretations of the interaction effects can be found above.

Excluding interactions, the variables in our final model include mean texture, smoothness, square root concavity, log compactness, and log area.

A summary of the coefficient estimate, standard error, and p value for each variable:

- The mean texture coefficient estimate is 0.5738 (+/- 0.1047 SE) with a p value of 4.23e-08.
- The mean smoothness coefficient estimate is 206.496 (+/- 43.8422 SE) with a p value of 2.48e-06.
- The mean square root transformed concavity coefficient estimate is 29.9367 (+/- 6.2486 SE) with a p value of 1.66e-06.
- The mean log transformed compactness coefficient estimate is -4.1492 (+/- 1.5654 SE) with a p value of 0.008035.
- The mean log transformed area coefficient estimate is 12.2830 (+/- 1.8590 SE) with a p value of 3.91e-11.

The next table shows the odds ratios for the parameter estimates of the final model and their 95% confidence intervals:

```
cbind.data.frame(exp.beta = exp(lm5$coefficients),
                 exp(as.data.frame (confint(lm5))))
```

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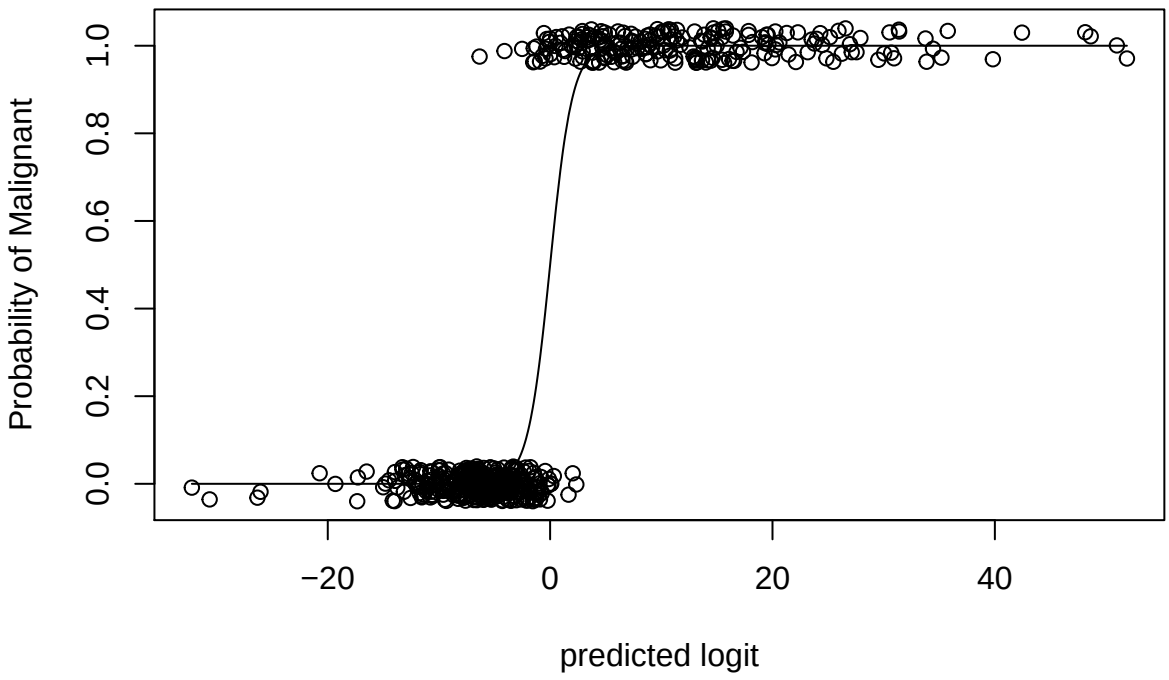
##                                         exp.beta         2.5 %        97.5 %
## (Intercept)                         2.959296e-01  1.491838e-01  5.407156e-01
## texture_mean.c                      1.774926e+00  1.475926e+00  2.237321e+00
## smoothness_mean.c                   4.787197e+89  3.635438e+55 6.580859e+130
## sqrtconcavity_mean.c                1.003115e+13  1.124503e+08  6.457269e+18
## logcompactness_mean.c               1.577735e-02  6.464031e-04  3.155600e-01
## logarea_mean.c                      2.159935e+05  8.844429e+03  1.394774e+07
## texture_mean.c:smoothness_mean.c    8.090891e+17  1.383352e+10  1.420765e+27
## texture_mean.c:sqrtconcavity_mean.c 1.118390e+02  7.735118e+00  2.501336e+03
## texture_mean.c:logcompactness_mean.c 2.630205e-01 1.225725e-01  5.240388e-01
## texture_mean.c:logarea_mean.c       2.798155e+00  1.415342e+00  6.170854e+00
## smoothness_mean.c:sqrtconcavity_mean.c       Inf 7.004449e+192           Inf
```

```r
# Final model plot
par(mfrow=c(1,1))
predpr = predict (lm5, type='response')
predlogit = predict (lm5)
plot (jitter (ifelse(wisconsin$diagnosis=='M',1,0), 0.2) ~ predlogit, xlab="predicted logit", ylab="Pro
pred.ord = order (predlogit)
lines (predlogit[pred.ord], predpr[pred.ord])
```



By observing the density of points when separated by our final model, there is a clear switch from benign to malignant tumor cells near the predicted logit of 0. The clear switch with little overlap from benign to malignant tumor cell responses as predicted logit increases suggests that our final model is well suited to accurately predict tumor diagnosis.

```
car::vif(lm5)
```

```
##                          texture_mean.c                       smoothness_mean.c
##                                2.727401                               4.862768
##                    sqrtconcavity_mean.c                   logcompactness_mean.c
##                                5.365662                               6.618617
##                          logarea_mean.c         texture_mean.c:smoothness_mean.c
##                                3.390512                               4.073068
##    texture_mean.c:sqrtconcavity_mean.c     texture_mean.c:logcompactness_mean.c
##                                5.396285                               6.524692
##          texture_mean.c:logarea_mean.c smoothness_mean.c:sqrtconcavity_mean.c
##                                1.795399                               2.413216
```

After centering predictors and step wise regression, we have addressed most of our previous problems with collinearity. Mean log compactness and mean sqrt concavity and a subset of the interactions in which these predictors are included have VIF values just slightly larger than 5 (maximum VIF = 6.62). This suggests that we may have some moderate collinearity issues, but given that the VIF values are only marginally larger than the cutoff, we are confident proceeding with this model.

Model Diagnostics

```
# Likelihood ratio test of final model
pchisq(lm5$null.deviance - lm5$deviance, lm5$df.null - lm5$df.residual, lower.tail = F)
```

```
## [1] 5.726579e-132
```

```
# Goodness of fit test of final model
1 - pchisq(lm5$deviance, lm5$df.residual)
```

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

The likelihood ratio test shows that the as a whole has a significant effect on tumor diagnosis (p = 5.726579e-132). This suggests that the final model is useful for predicting diagnosis.

The goodness of fit test shows that the final model is not significantly different from a saturated model (p= 1). This suggests that our model is capturing most of the nuance in the association between the predictors and diagnosis and that there is no significant lack of fit.

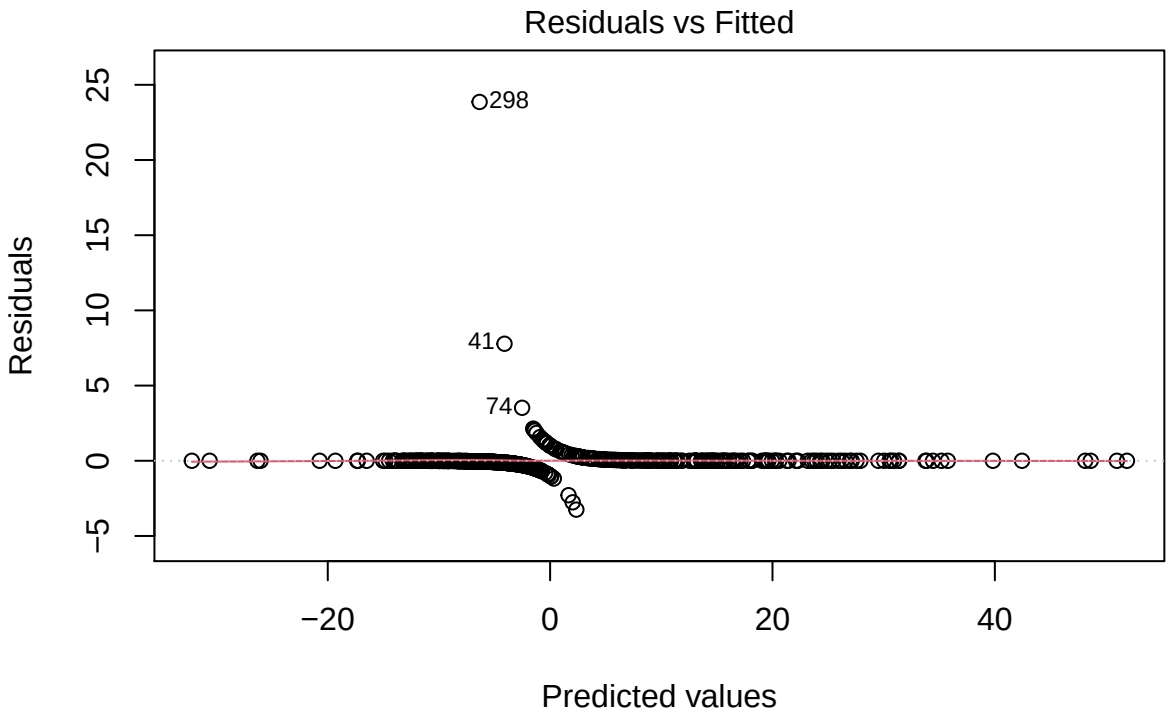
Residual Plots and influence analysis

```
levcut = 2*(sqrt(11/569))
levcut
```

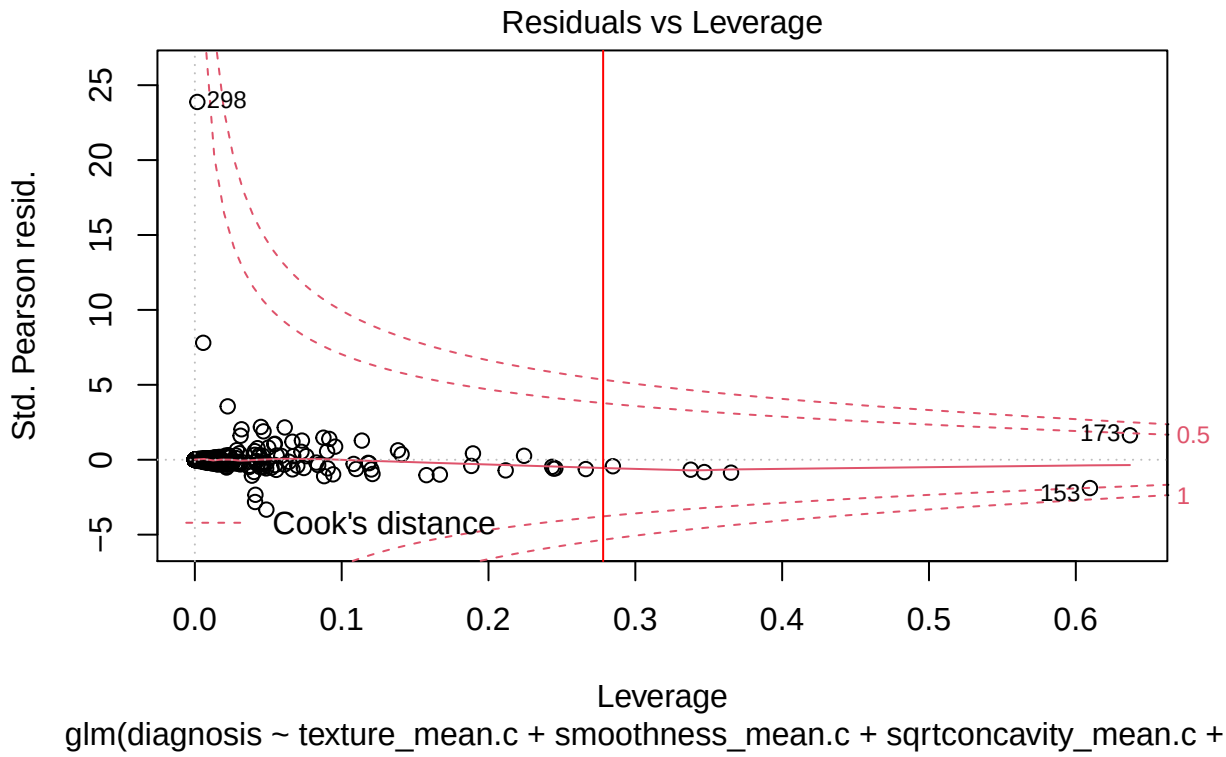
```
## [1] 0.2780803
```

The leverage cut off is 0.278.

```
par(mfrow=c(1,1))
plot(lm5, which = c(1))
```




```
plot(lm5, which = c(5))
abline(v=levcut, col="red")
```




```
hatvals = hatvalues(lm5) > levcut
sum(hatvals)/569
```

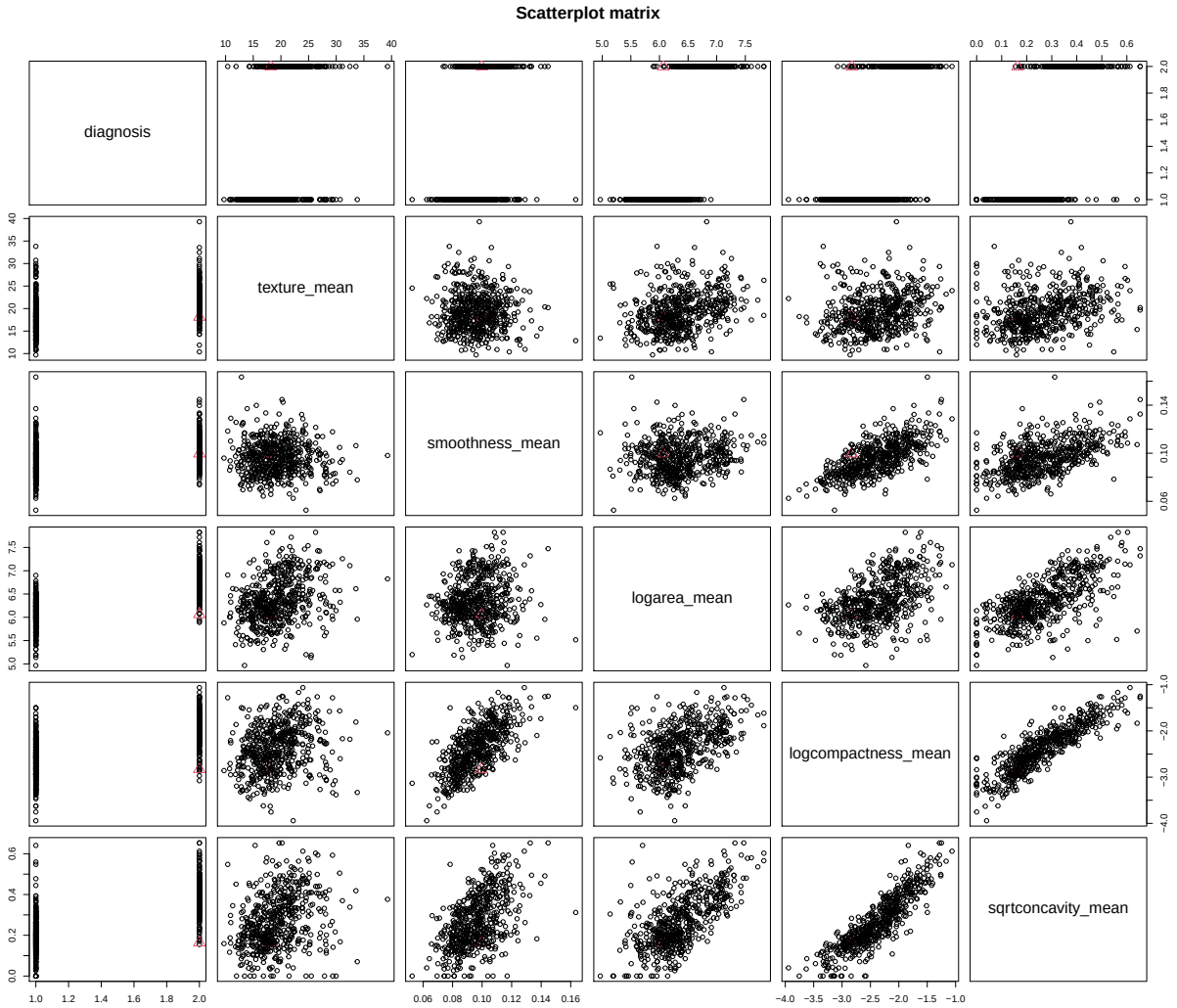
```
## [1] 0.01054482
```

```
# summary of cooks distances
cooks <- as.data.frame(cooks.distance(lm5))
```

The smoothing spline in the residual plot for our first order model has little deviation from zero which suggests that our model has successfully met the assumption of linearity.

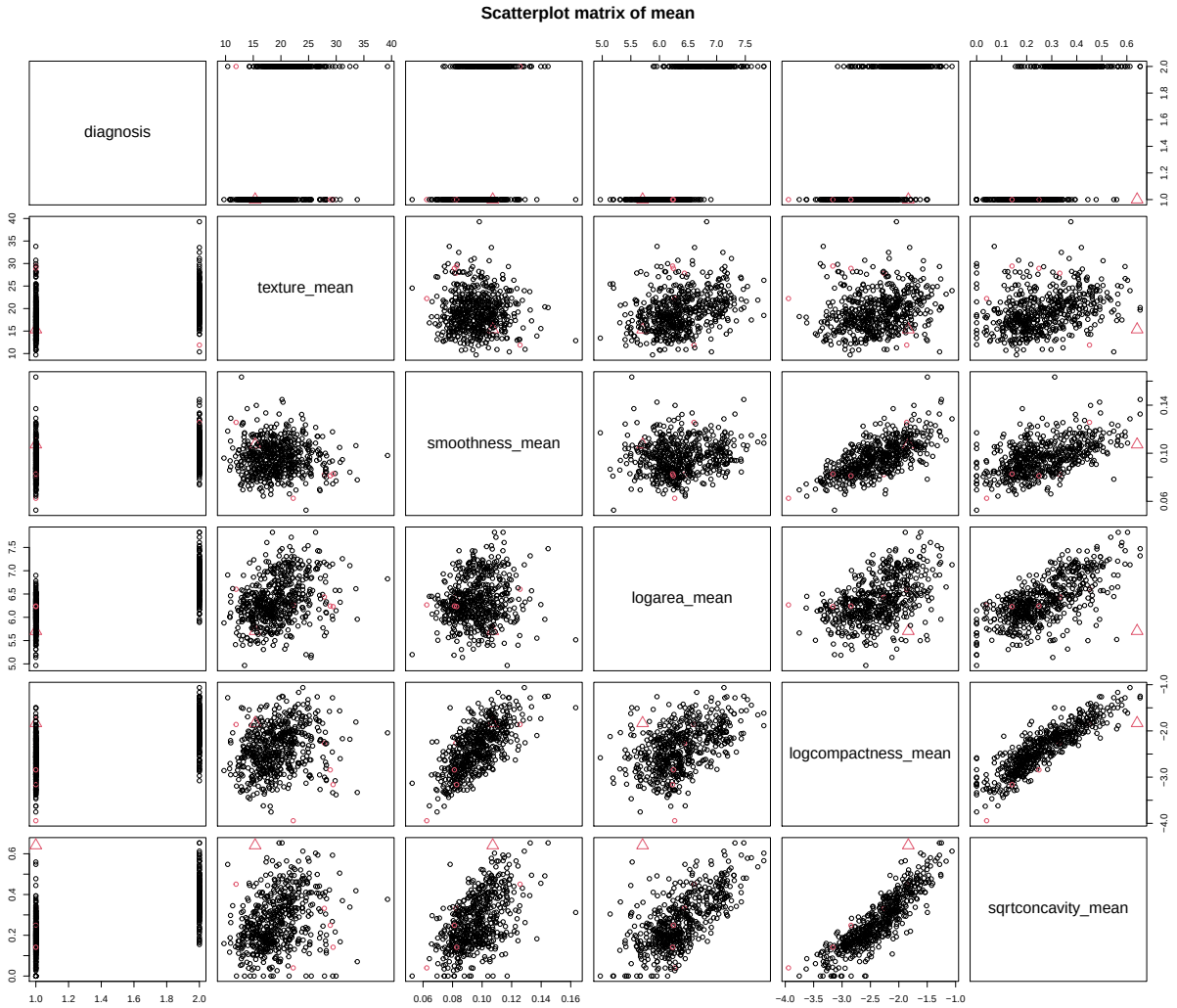
There are 6 samples (1.05% of the sample size) with leverage values above the cutoff. This is less than the expected 5% and suggests that the large majority of the samples in our sample have similar values for our predictor variables. Sample 153 and 173 have the highest leverage. While sample 173 is not quite influential, point 153 is a moderate influence point with a cooks distance value of .507. Points 41 and 298, while not influential due to low leverage, have very high positive residuals above the cut off of +/- 4 for standardized pearson residuals. Point 298 and 153 along with all influential points will be highlighted in a scatter plot matrix to examine the cause of their high leverage and residuals.

```
# Highlighting point 298 with a red triangle
pairs(wisconsin[, c(1, 3, 6, 12:14)], col= ifelse(1:569==298, 2, 1), cex=ifelse(1:569==298, 2, 1), pch=
```



As expected from the low influence value of sample 298, its values for each individual predictor variable are close to the mean value of all the cases. When separating cases by diagnosis however, sample 298's values for mean log area, log compactness, and square root concavity are towards the far left end of the distribution of malignant cases. These predictor variable values which are more associated with benign diagnosis rather than malignant diagnosis are likely the reason for the large standardized pearson residual. Because sample 298 is not influential and there is no clear evidence of data misentry or a plausible explanation for its odd pattern, we will leave sample 298 in our data set.

```
# Highlighting point 153 as a triangle and coloring all high leverage points
pairs(wisconsin[, c(1, 3, 6, 12:14)], col= (hatvals > levcut) + 1, cex=ifelse(1:569==153, 2, 1), pch=if
```



It appears that sample 153, one of our highest leverage points and the only moderately influential point in our data set, is explained primarily by its mean square root concavity value. Sample 153 has a mean square root concavity value that is towards the far right side of the distribution of this predictor for all cases making it the primary contributor to the samples high leverage. Additionally, when looking only at benign cases, sample 153's mean square root concavity measurement is even more abnormally large. It appears that this mean square root concavity value in addition to an abnormally large mean log compactness measurement for benign cases are the primary contributors to the samples residual magnitude. Because sample 153 is just barely moderately influential, we will keep it in our data set and proceed with the current model without any remedial measures.

ROC Curve

```
par(mfrow= c(1, 1))
library(ROCR)
```

```
## Warning: package 'ROCR' was built under R version 4.0.5
```

```
pred1 <- prediction(lm5$fitted.values, lm5$y)
perf1 <- performance(pred1,"tpr","fpr")
```

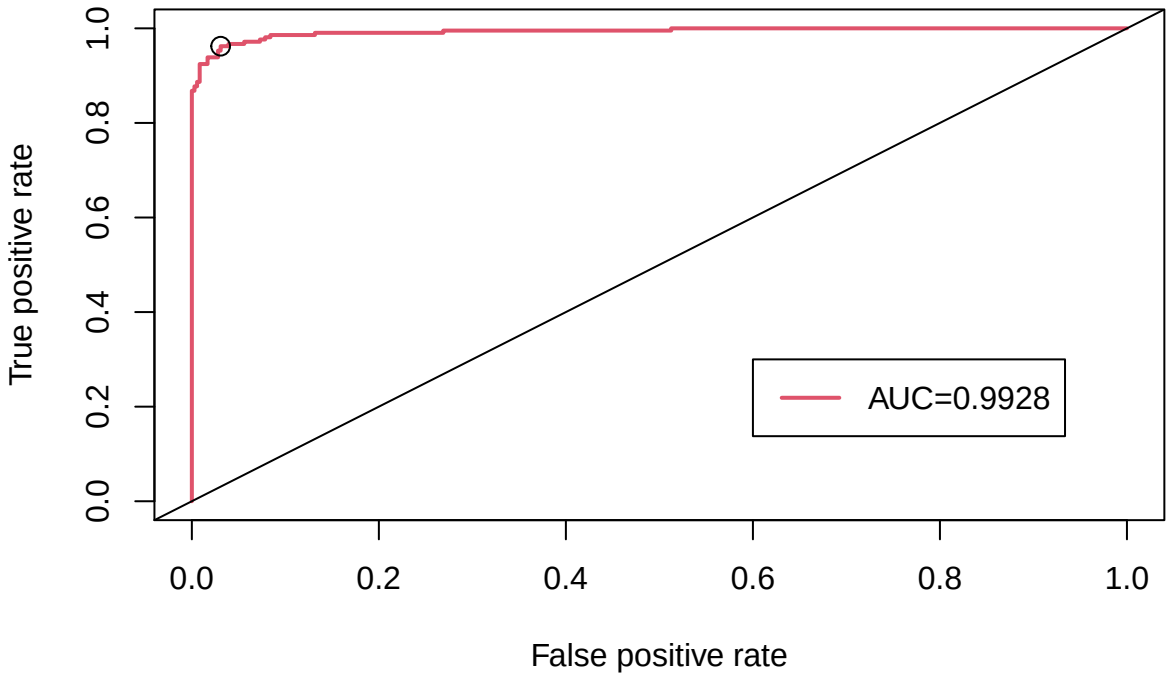
```r
auc1 <- performance(pred1,"auc")@y.values[[1]]
auc1
```

```
## [1] 0.9928122
```

```r
plot(perf1, lwd=2, col=2)
abline(0,1)
legend(0.6, 0.3, c(paste("AUC=", round(auc1,4), sep="")), lwd = 2, col=2)
roc.x = slot(perf1, "x.values") [[1]]
roc.y = slot(perf1, "y.values") [[1]]
cutoffs = slot(perf1, "alpha.values") [[1]]

auc.table = cbind.data.frame(cutoff = pred1@cutoffs, tp=pred1@tp, fp=pred1@fp, tn=pred1@tn, fn=pred1@fn

names(auc.table) = c("Cutoff","TP","FP","TN","FN")
auc.table$sensitivity = auc.table$TP / (auc.table$TP + auc.table$FN)
auc.table$specificity = auc.table$TN / (auc.table$TN + auc.table$FP)
auc.table$FalsePosRate = 1 - auc.table$specificity
auc.table$sens_spec = auc.table$sensitivity + auc.table$specificity
auc.table$ppv = auc.table$TP / (auc.table$TP + auc.table$FP)
auc.table$npv = auc.table$TN / (auc.table$TN + auc.table$FN)

auc.best = auc.table[auc.table$sens_spec == max(auc.table$sens_spec),]
auc.best
```

```
##        Cutoff  TP FP  TN FN sensitivity specificity FalsePosRate sens_spec
## 185 0.3361295 204 11 346  8   0.9622642   0.9691877   0.03081232  1.931452
##           ppv       npv
## 185 0.9488372 0.9774011
```

```r
points(auc.best$FalsePosRate, auc.best$sensitivity, cex=1.3)
```



Our concordance index is 0.9928, meaning that the model is highly effective at predicting tumor diagnosis. Our optimal cutoff for determining whether a case is benign or malignant was 0.3361. This value maximized sensitivity and specificity. At this cut off the true positive rate or sensitivity was 0.962 and the true negative rate or specificity was 0.969. The positive predictive value or the probability that cases with a malignant prediction are truly malignant is 0.949. The negative predictive value or the probability that cases with a prediction are truly benign is 0.977. Again, these values suggest that our model is highly effective at predicting tumor diagnosis with minimal false predictions.

Predictions using the final model

```
preds = predict (lm5, se.fit = T)
pred.df = cbind.data.frame (wisconsin, as.data.frame (preds))
pred.df$lwr = pred.df$fit - 1.96 * pred.df$se.fit
pred.df$upr = pred.df$fit + 1.96 * pred.df$se.fit
pred.df$fit.pr = round (exp (pred.df$fit) / (1 + exp (pred.df$fit)), 3)
pred.df$lwr.pr = round (exp (pred.df$lwr) / (1 + exp (pred.df$lwr)), 3)
pred.df$upr.pr = round (exp (pred.df$upr) / (1 + exp (pred.df$upr)), 3)

pred.df [c(2, 10, 298, 38, 68, 129), c(1, 16:17, 19, 21:22, 28:30)]
```

```
##     diagnosis texture_mean.c smoothness_mean.c sqrtconcavity_mean.c
## 2           M     -1.5196485      -0.011620281           0.02743367
## 10          M      4.7503515       0.022239719           0.20940551
## 298         M     -1.1496485       0.003319719          -0.10349469
## 38          B     -0.8696485      -0.006530281          -0.10729190
```

```
## 68          B     -0.2496485      -0.014970281          -0.07476675
## 129         B     -2.8996485       0.018639719           0.06998816
##     logcompactness_mean.c logarea_mean.c fit.pr lwr.pr upr.pr
## 2              -0.1623572      0.8267372  0.997  0.968  1.000
## 10              0.9517332     -0.1979772  1.000  0.999  1.000
## 298            -0.4473302     -0.2968448  0.002  0.000  0.012
## 38             -0.8986392     -0.1020750  0.032  0.005  0.181
## 68             -0.6768774     -0.3865802  0.001  0.000  0.005
## 129             0.6696005      0.1507867  0.913  0.694  0.980
```

In order to test how effective our final model is, we made 3 predictions of malignant samples and 3 predictions of benign samples. Our prediction cut off as determined by AUC, which maximizes sensitivity and specificity is 0.3361. Any cases with probabilities above this threshold are predicted to be malignant whereas cases with probabilities below this threshold are predicted to be benign. To challenge our model we included in our predictions sample 298, our highest positive residual, and sample 129, our largest negative residual. Our model correctly predicted 4 of these 6 cases.

Outside of case 298 and 129, our model correctly predicted the other cases relatively easily given that the prediction interval for these predictions did not come close to overlapping with the established cut off.

```
pred.df$pred.fail = ifelse (pred.df$fit.pr >= auc.best$Cutoff[1], "Pred.Yes",
"Pred.No")
table (wisconsin$diagnosis, pred.df$pred.fail)
```

```
##
##     Pred.No Pred.Yes
##   B     346       11
##   M       9      203
```

In order to situate our 6 predictions within the context of the full data set we revisit the contingency table. Altogether, our model correctly predicted 96.2% of malignant cases and 96.9% of benign cases suggesting that our 2 incorrect predictions were representative of a very small proportion of incorrectly identified cases in the entire data set. Overall, our model is very accurate and highly effective for predicting tumor diagnosis with very few false predictions.

Conclusions

Altogether, our model shows that mean texture, smoothness, square root concavity, log compactness, and log area are significant predictors of tumor diagnosis. Between these variables there were significant interactions between texture and smoothness, square root concavity, log compactness, and log area as well as an interaction between smoothness and square root concavity. The AUC of this model was .9928 which shows that this combination of predictors is very effective at predicting tumor diagnosis. A high p value (p= 1) for a goodness of fit test of the model shows that there is no significant lack of fit. The accuracy of the model at predicting both benign and malignant tumors is shown by the sensitivity and specificity at the established cut off. Altogether, 96.2% of malignant cases and 96.9% of benign cases were correctly predicted by our model.

What questions are not answered by our model?

-We wonder how well our our model would perform given new data. It would be interesting to conduct cross validation to test this.

-Additionally, we are curious to learn more about how models like this one are applied in health care. Is it good enough to stand-in for an actual doctor making a diagnosis? Could these models be applicable to other kinds of cancers as well?

-It would be interesting to better understand the biological basis for the trends we observed in predictor variables, especially in the interaction effects. For instance, why is texture strongly associated with breast cancer when cells are relatively large, but not when cells are smaller?

- An explanation for the abnormal pattern of sample 298 could lead to interesting/important scientific findings.