Project 2: Breast Cancer Diagnosis

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Objectives

A mammogram is an X-ray image of breast tissue. It can help save lives because it is easier to treat breast cancer in its early stages before the cancer is big enough to detect or cause symptoms. However, a wrong diagnosis can have a negative impact on patients. For example, if there is a false-positive test result, the doctor sees something that looks like cancer but is not. This could result in overtreatment that causes unnecessary side effects on patients. On the other hand, false-negative test result occurs when a doctor misses cancer tissues, which may delay the treatment. Therefore, building a model that gives an accurate classification of the tissue images is necessary to give proper treatment. In our study, we collected 569 images from both malignant and benign cancer tissues. Our goal is to build a predictive model to facilitate cancer diagnosis.

Dataset

Our data set consistes of 569 rows, with 357 benign and 212 malignant. We denote 0 for benign and 1 for malignant. We also have 30 columns representing the features of the tissue images. They include the mean, standard deviation, and the largest values of the distributions of the following 10 features computed for the cell nuclei:

- radius (mean of distances from center to points on the perimeter)
- texture (standard deviation of gray-scale values)
- perimeter
- area
- smoothness (local variation in radius lengths)
- compactness ($perimeter^2/area$ - 1.0)
- concavity (severity of concave portions of the contour)
- concave points (number of concave portions of the contour)
- symmetry
- fractal dimension ("coastline approximation" - 1)

Methods

Variables Selection

Among the 30 explanatory variables that we have, not all of them are necessary for the prediction model. Therefore, we dropped the columns that have high correlation with other columns. The 11 variables we left in the end have correlations less than 0.7 with each other.

Logistic Model

Let y be the vector with 569 binary response variable, X be the 569×11 matrix with 11 numerical explanatory variables, and β be the vector with 11 corresponding coefficients. We also have β_0 as the intercepts.

For our logistic model, the probability of ith row be a malignant tissue is given by:

$$P(y_i = 1|X_i) = \frac{e^{\beta_0+\beta X_i}}{1 + e^{\beta_0+\beta X_i}}.$$

For likelihood function is:

$$L(\beta_0, \beta) = \prod_{i=1}^{n} [(\frac{e^{\beta_0+\beta X_i}}{1 + e^{\beta_0+\beta X_i}})^{y_i} (\frac{1}{1 + e^{\beta_0+\beta X_i}})^{1-y_i}].$$

Maximizing the likelihood is equivalent to maximizing the log likelihood:

$$f(\beta_0, \beta) = \sum_{i=1}^{n} [y_i(\beta_0 + \beta X_i) - \log(1 + e^{\beta_0+\beta X_i})].$$

The gradient of this function is:

$$\nabla f(\beta_0, \beta) =$$

Results

Conclusions

Appendix

Data preparation

```
#load the data
breast_dat = read_csv("breast-cancer.csv") %>%
  janitor::clean_names() %>%
  select(-33) %>% #drop NA column
  add_row(id = 92751, diagnosis = "B", radius_mean = 7.76, texture_mean = 24.54,
          perimeter_mean = 47.92, area_mean = 181, smoothness_mean = 0.05263,
          compactness_mean = 0.04362, concavity_mean = 0,
          concave_points_mean = 0, symmetry_mean = 0.1587,
          fractal_dimension_mean = 0.05884, radius_se = 0.3857,
          texture_se = 1.428, perimeter_se = 2.548, area_se = 19.15,
          smoothness_se = 0.007189, compactness_se = 0.00466, concavity_se = 0,
```

```
          concave_points_se = 0, symmetry_se = 0.02676,
          fractal_dimension_se = 0.002783, radius_worst = 9.456,
          texture_worst = 30.37, perimeter_worst = 59.16, area_worst = 268.6,
          smoothness_worst = 0.08996, compactness_worst = 0.06444,
          concavity_worst = 0, concave_points_worst = 0,
          symmetry_worst = 0.2871, fractal_dimension_worst = 0.07039)
  #add missing row


head(breast_dat, 5)
```

```
## # A tibble: 5 x 32
##         id diagnosis radius_mean texture_mean perimeter_mean area_mean
##      <dbl> <chr>           <dbl>        <dbl>          <dbl>     <dbl>
## 1   842302 M                18.0         10.4          123.      1001
## 2   842517 M                20.6         17.8          133.      1326
## 3 84300903 M                19.7         21.2          130       1203
## 4 84348301 M                11.4         20.4           77.6      386.
## 5 84358402 M                20.3         14.3          135.      1297
## # ... with 26 more variables: smoothness_mean <dbl>, compactness_mean <dbl>,
## #   concavity_mean <dbl>, concave_points_mean <dbl>, symmetry_mean <dbl>,
## #   fractal_dimension_mean <dbl>, radius_se <dbl>, texture_se <dbl>,
## #   perimeter_se <dbl>, area_se <dbl>, smoothness_se <dbl>,
## #   compactness_se <dbl>, concavity_se <dbl>, concave_points_se <dbl>,
## #   symmetry_se <dbl>, fractal_dimension_se <dbl>, radius_worst <dbl>,
## #   texture_worst <dbl>, perimeter_worst <dbl>, area_worst <dbl>, ...
```

```
r = dim(breast_dat)[1] #row number
c = dim(breast_dat)[2] #column number

var_names = names(breast_dat)[-c(1,2)] #variable names

standardize = function(col) {
  mean = mean(col)
  sd = sd(col)
  return((col - mean)/sd)
}

stand_df = breast_dat %>%
  dplyr::select(radius_mean:fractal_dimension_worst) %>%
  map_df(.x = ., standardize) #standardize

X = stand_df #predictors
y = as.vector(ifelse(breast_dat[,2] == "M", 1, 0))#response
```

Check collinearity

```
corr = stand_df %>%
  cor()
corr
```

```
##                          radius_mean texture_mean perimeter_mean    area_mean
## radius_mean              1.000000000  0.323781891    0.997855281  0.987357170
## texture_mean             0.323781891  1.000000000    0.329533059  0.321085696
## perimeter_mean           0.997855281  0.329533059    1.000000000  0.986506804
## area_mean                0.987357170  0.321085696    0.986506804  1.000000000
## smoothness_mean          0.170581187 -0.023388516    0.207278164  0.177028377
## compactness_mean         0.506123578  0.236702222    0.556936211  0.498501682
## concavity_mean           0.676763550  0.302417828    0.716135650  0.685982829
## concave_points_mean      0.822528522  0.293464051    0.850977041  0.823268869
## symmetry_mean            0.147741242  0.071400980    0.183027212  0.151293079
## fractal_dimension_mean  -0.311630826 -0.076437183   -0.261476908 -0.283109812
## radius_se                0.679090388  0.275868676    0.691765014  0.732562227
## texture_se              -0.097317443  0.386357623   -0.086761078 -0.066280214
## perimeter_se             0.674171616  0.281673115    0.693134890  0.726628328
## area_se                  0.735863663  0.259844987    0.744982694  0.800085921
## smoothness_se           -0.222600125  0.006613777   -0.202694026 -0.166776667
## compactness_se           0.205999980  0.191974611    0.250743681  0.212582551
## concavity_se             0.194203623  0.143293077    0.228082345  0.207660060
## concave_points_se        0.376168956  0.163851025    0.407216916  0.372320282
## symmetry_se             -0.104320881  0.009127168   -0.081629327 -0.072496588
## fractal_dimension_se    -0.042641269  0.054457520   -0.005523391 -0.019886963
## radius_worst             0.969538973  0.352572947    0.969476363  0.962746086
## texture_worst            0.297007644  0.912044589    0.303038372  0.287488627
## perimeter_worst          0.965136514  0.358039575    0.970386887  0.959119574
## area_worst               0.941082460  0.343545947    0.941549808  0.959213326
## smoothness_worst         0.119616140  0.077503359    0.150549404  0.123522939
## compactness_worst        0.413462823  0.277829592    0.455774228  0.390410309
## concavity_worst          0.526911462  0.301025224    0.563879263  0.512605920
## concave_points_worst     0.744214198  0.295315843    0.771240789  0.722016626
## symmetry_worst           0.163953335  0.105007910    0.189115040  0.143569914
## fractal_dimension_worst  0.007065886  0.119205351    0.051018530  0.003737597
##                          smoothness_mean compactness_mean concavity_mean
## radius_mean                   0.17058119       0.50612358     0.67676355
## texture_mean                 -0.02338852       0.23670222     0.30241783
## perimeter_mean                0.20727816       0.55693621     0.71613565
## area_mean                     0.17702838       0.49850168     0.68598283
## smoothness_mean               1.00000000       0.65912322     0.52198377
## compactness_mean              0.65912322       1.00000000     0.88312067
## concavity_mean                0.52198377       0.88312067     1.00000000
## concave_points_mean           0.55369517       0.83113504     0.92139103
## symmetry_mean                 0.55777479       0.60264105     0.50066662
## fractal_dimension_mean        0.58479200       0.56536866     0.33678336
## radius_se                     0.30146710       0.49747345     0.63192482
## texture_se                    0.06840645       0.04620483     0.07621835
## perimeter_se                  0.29609193       0.54890526     0.66039079
## area_se                       0.24655243       0.45565285     0.61742681
## smoothness_se                 0.33237544       0.13529927     0.09856375
## compactness_se                0.31894330       0.73872179     0.67027882
## concavity_se                  0.24839568       0.57051687     0.69127021
## concave_points_se             0.38067569       0.64226185     0.68325992
## symmetry_se                   0.20077438       0.22997659     0.17800921
## fractal_dimension_se          0.28360670       0.50731813     0.44930075
## radius_worst                  0.21312014       0.53531540     0.68823641
## texture_worst                 0.03607180       0.24813283     0.29987889
```

```
## perimeter_worst              0.23885263       0.59021043     0.72956492
## area_worst                   0.20671836       0.50960381     0.67598723
## smoothness_worst             0.80532420       0.56554117     0.44882204
## compactness_worst            0.47246844       0.86580904     0.75496802
## concavity_worst              0.43492571       0.81627525     0.88410264
## concave_points_worst         0.50305335       0.81557322     0.86132303
## symmetry_worst               0.39430948       0.51022343     0.40946413
## fractal_dimension_worst      0.49931637       0.68738232     0.51492989
##                         concave_points_mean symmetry_mean
## radius_mean                       0.82252852    0.14774124
## texture_mean                      0.29346405    0.07140098
## perimeter_mean                    0.85097704    0.18302721
## area_mean                         0.82326887    0.15129308
## smoothness_mean                   0.55369517    0.55777479
## compactness_mean                  0.83113504    0.60264105
## concavity_mean                    0.92139103    0.50066662
## concave_points_mean               1.00000000    0.46249739
## symmetry_mean                     0.46249739    1.00000000
## fractal_dimension_mean            0.16691738    0.47992133
## radius_se                         0.69804983    0.30337926
## texture_se                        0.02147958    0.12805293
## perimeter_se                      0.71064987    0.31389276
## area_se                           0.69029854    0.22397022
## smoothness_se                     0.02765331    0.18732117
## compactness_se                    0.49042425    0.42165915
## concavity_se                      0.43916707    0.34262702
## concave_points_se                 0.61563413    0.39329787
## symmetry_se                       0.09535079    0.44913654
## fractal_dimension_se              0.25758375    0.33178615
## radius_worst                      0.83031763    0.18572775
## texture_worst                     0.29275171    0.09065069
## perimeter_worst                   0.85592313    0.21916856
## area_worst                        0.80962962    0.17719338
## smoothness_worst                  0.45275305    0.42667503
## compactness_worst                 0.66745368    0.47320001
## concavity_worst                   0.75239950    0.43372101
## concave_points_worst              0.91015531    0.43029661
## symmetry_worst                    0.37574415    0.69982580
## fractal_dimension_worst           0.36866113    0.43841350
##                         fractal_dimension_mean    radius_se  texture_se
## radius_mean                     -0.3116308263 0.6790903880 -0.09731744
## texture_mean                    -0.0764371834 0.2758686762  0.38635762
## perimeter_mean                  -0.2614769081 0.6917650135 -0.08676108
## area_mean                       -0.2831098117 0.7325622270 -0.06628021
## smoothness_mean                  0.5847920019 0.3014670983  0.06840645
## compactness_mean                 0.5653686634 0.4974734461  0.04620483
## concavity_mean                   0.3367833594 0.6319248221  0.07621835
## concave_points_mean              0.1669173832 0.6980498336  0.02147958
## symmetry_mean                    0.4799213301 0.3033792632  0.12805293
## fractal_dimension_mean           1.0000000000 0.0001109951  0.16417397
## radius_se                        0.0001109951 1.0000000000  0.21324734
## texture_se                       0.1641739659 0.2132473373  1.00000000
## perimeter_se                     0.0398299316 0.9727936770  0.22317073
## area_se                         -0.0901702475 0.9518301121  0.11156725
```

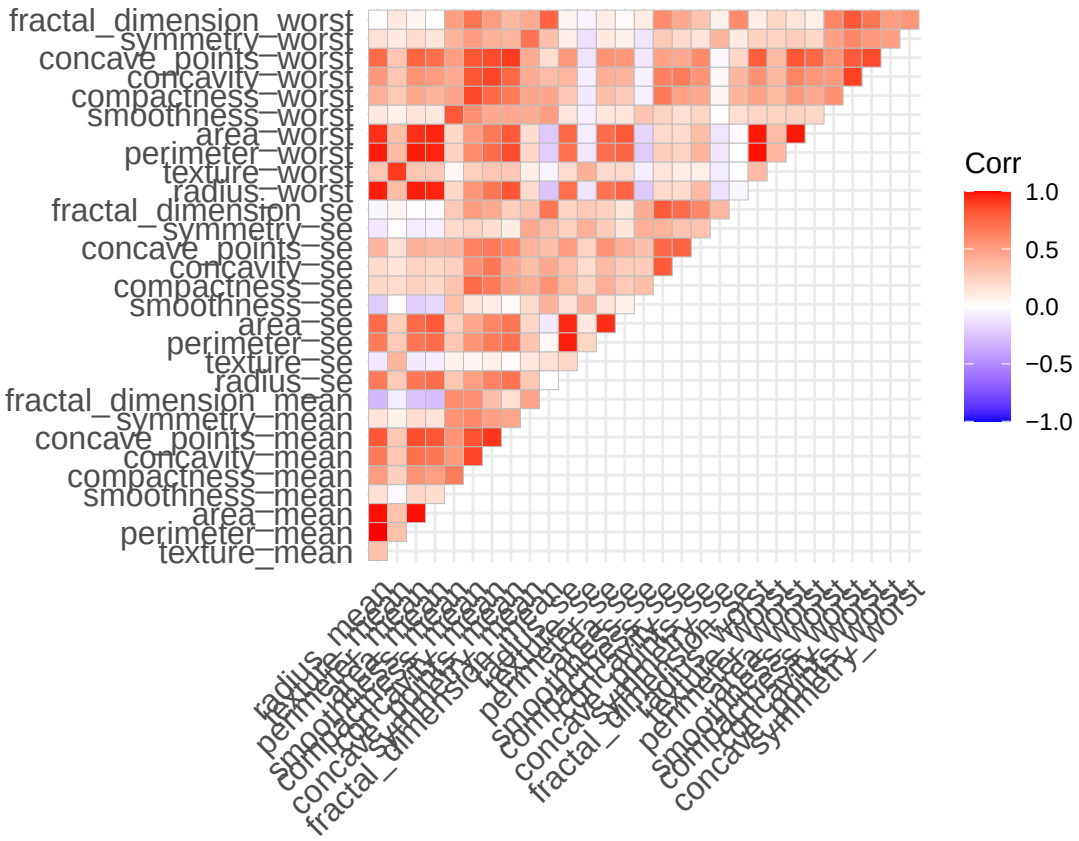
```
## smoothness_se                    0.4019644254 0.1645142198  0.39724285
## compactness_se                   0.5598366906 0.3560645755  0.23169970
## concavity_se                     0.4466303217 0.3323575376  0.19499846
## concave_points_se                0.3411980444 0.5133464414  0.23028340
## symmetry_se                      0.3450073971 0.2405673625  0.41162068
## fractal_dimension_se             0.6881315775 0.2277535327  0.27972275
## radius_worst                    -0.2536914949 0.7150651951 -0.11169031
## texture_worst                   -0.0512692020 0.1947985568  0.40900277
## perimeter_worst                 -0.2051512113 0.7196838037 -0.10224192
## area_worst                      -0.2318544512 0.7515484761 -0.08319499
## smoothness_worst                 0.5049420754 0.1419185529 -0.07365766
## compactness_worst                0.4587981567 0.2871031656 -0.09243935
## concavity_worst                  0.3462338763 0.3805846346 -0.06895622
## concave_points_worst             0.1753254492 0.5310623278 -0.11963752
## symmetry_worst                   0.3340186839 0.0945428304 -0.12821476
## fractal_dimension_worst          0.7672967792 0.0495594325 -0.04565457
##                         perimeter_se     area_se smoothness_se compactness_se
## radius_mean               0.67417162  0.73586366  -0.222600125      0.2060000
## texture_mean              0.28167311  0.25984499   0.006613777      0.1919746
## perimeter_mean            0.69313489  0.74498269  -0.202694026      0.2507437
## area_mean                 0.72662833  0.80008592  -0.166776667      0.2125826
## smoothness_mean           0.29609193  0.24655243   0.332375443      0.3189433
## compactness_mean          0.54890526  0.45565285   0.135299268      0.7387218
## concavity_mean            0.66039079  0.61742681   0.098563746      0.6702788
## concave_points_mean       0.71064987  0.69029854   0.027653308      0.4904242
## symmetry_mean             0.31389276  0.22397022   0.187321165      0.4216591
## fractal_dimension_mean    0.03982993 -0.09017025   0.401964425      0.5598367
## radius_se                 0.97279368  0.95183011   0.164514220      0.3560646
## texture_se                0.22317073  0.11156725   0.397242853      0.2316997
## perimeter_se              1.00000000  0.93765541   0.151075331      0.4163224
## area_se                   0.93765541  1.00000000   0.075150338      0.2848401
## smoothness_se             0.15107533  0.07515034   1.000000000      0.3366961
## compactness_se            0.41632237  0.28484006   0.336696081      1.0000000
## concavity_se              0.36248158  0.27089473   0.268684760      0.8012683
## concave_points_se         0.55626408  0.41572957   0.328429499      0.7440827
## symmetry_se               0.26648709  0.13410898   0.413506125      0.3947128
## fractal_dimension_se      0.24414277  0.12707090   0.427374207      0.8032688
## radius_worst              0.69720059  0.75737319  -0.230690710      0.2046072
## texture_worst             0.20037085  0.19649665  -0.074742965      0.1430026
## perimeter_worst           0.72103131  0.76121264  -0.217303755      0.2605158
## area_worst                0.73071297  0.81140796  -0.182195478      0.1993713
## smoothness_worst          0.13005439  0.12538943   0.314457456      0.2273942
## compactness_worst         0.34191945  0.28325654  -0.055558139      0.6787804
## concavity_worst           0.41889882  0.38510014  -0.058298387      0.6391467
## concave_points_worst      0.55489723  0.53816631  -0.102006796      0.4832083
## symmetry_worst            0.10993043  0.07412629  -0.107342098      0.2778784
## fractal_dimension_worst   0.08543257  0.01753930   0.101480315      0.5909728
##                         concavity_se concave_points_se  symmetry_se
## radius_mean                0.1942036        0.37616896 -0.104320881
## texture_mean               0.1432931        0.16385103  0.009127168
## perimeter_mean             0.2280823        0.40721692 -0.081629327
## area_mean                  0.2076601        0.37232028 -0.072496588
## smoothness_mean            0.2483957        0.38067569  0.200774376
## compactness_mean           0.5705169        0.64226185  0.229976591
```

```
## concavity_mean             0.6912702        0.68325992  0.178009208
## concave_points_mean        0.4391671        0.61563413  0.095350787
## symmetry_mean              0.3426270        0.39329787  0.449136542
## fractal_dimension_mean     0.4466303        0.34119804  0.345007397
## radius_se                  0.3323575        0.51334644  0.240567362
## texture_se                 0.1949985        0.23028340  0.411620680
## perimeter_se               0.3624816        0.55626408  0.266487092
## area_se                    0.2708947        0.41572957  0.134108980
## smoothness_se              0.2686848        0.32842950  0.413506125
## compactness_se             0.8012683        0.74408267  0.394712835
## concavity_se               1.0000000        0.77180399  0.309428578
## concave_points_se          0.7718040        1.00000000  0.312780223
## symmetry_se                0.3094286        0.31278022  1.000000000
## fractal_dimension_se       0.7273722        0.61104414  0.369078083
## radius_worst               0.1869035        0.35812667 -0.128120769
## texture_worst              0.1002410        0.08674121 -0.077473420
## perimeter_worst            0.2266804        0.39499925 -0.103753044
## area_worst                 0.1883527        0.34227116 -0.110342743
## smoothness_worst           0.1684813        0.21535060 -0.012661800
## compactness_worst          0.4848578        0.45288838  0.060254879
## concavity_worst            0.6625641        0.54959238  0.037119049
## concave_points_worst       0.4404723        0.60244961 -0.030413396
## symmetry_worst             0.1977878        0.14311567  0.389402485
## fractal_dimension_worst    0.4393293        0.31065455  0.078079476
##                        fractal_dimension_se radius_worst texture_worst
## radius_mean                    -0.042641269   0.96953897   0.297007644
## texture_mean                    0.054457520   0.35257295   0.912044589
## perimeter_mean                 -0.005523391   0.96947636   0.303038372
## area_mean                      -0.019886963   0.96274609   0.287488627
## smoothness_mean                 0.283606699   0.21312014   0.036071799
## compactness_mean                0.507318127   0.53531540   0.248132833
## concavity_mean                  0.449300749   0.68823641   0.299878889
## concave_points_mean             0.257583746   0.83031763   0.292751713
## symmetry_mean                   0.331786146   0.18572775   0.090650688
## fractal_dimension_mean          0.688131577  -0.25369149  -0.051269202
## radius_se                       0.227753533   0.71506520   0.194798557
## texture_se                      0.279722748  -0.11169031   0.409002766
## perimeter_se                    0.244142773   0.69720059   0.200370854
## area_se                         0.127070903   0.75737319   0.196496649
## smoothness_se                   0.427374207  -0.23069071  -0.074742965
## compactness_se                  0.803268818   0.20460717   0.143002583
## concavity_se                    0.727372184   0.18690352   0.100240984
## concave_points_se               0.611044139   0.35812667   0.086741210
## symmetry_se                     0.369078083  -0.12812077  -0.077473420
## fractal_dimension_se            1.000000000  -0.03748762  -0.003195029
## radius_worst                   -0.037487618   1.00000000   0.359920754
## texture_worst                  -0.003195029   0.35992075   1.000000000
## perimeter_worst                -0.001000398   0.99370792   0.365098245
## area_worst                     -0.022736147   0.98401456   0.345842283
## smoothness_worst                0.170568316   0.21657443   0.225429415
## compactness_worst               0.390158842   0.47582004   0.360832339
## concavity_worst                 0.379974661   0.57397471   0.368365607
## concave_points_worst            0.215204013   0.78742385   0.359754610
## symmetry_worst                  0.111093956   0.24352920   0.233027461
```

```
## fractal_dimension_worst          0.591328066   0.09349198   0.219122425
##                          perimeter_worst  area_worst smoothness_worst
## radius_mean                  0.965136514  0.94108246       0.11961614
## texture_mean                 0.358039575  0.34354595       0.07750336
## perimeter_mean               0.970386887  0.94154981       0.15054940
## area_mean                    0.959119574  0.95921333       0.12352294
## smoothness_mean              0.238852626  0.20671836       0.80532420
## compactness_mean             0.590210428  0.50960381       0.56554117
## concavity_mean               0.729564917  0.67598723       0.44882204
## concave_points_mean          0.855923128  0.80962962       0.45275305
## symmetry_mean                0.219168559  0.17719338       0.42667503
## fractal_dimension_mean      -0.205151211 -0.23185445       0.50494208
## radius_se                    0.719683804  0.75154848       0.14191855
## texture_se                  -0.102241922 -0.08319499      -0.07365766
## perimeter_se                 0.721031310  0.73071297       0.13005439
## area_se                      0.761212636  0.81140796       0.12538943
## smoothness_se               -0.217303755 -0.18219548       0.31445746
## compactness_se               0.260515840  0.19937133       0.22739423
## concavity_se                 0.226680426  0.18835265       0.16848132
## concave_points_se            0.394999252  0.34227116       0.21535060
## symmetry_se                 -0.103753044 -0.11034274      -0.01266180
## fractal_dimension_se        -0.001000398 -0.02273615       0.17056832
## radius_worst                 0.993707916  0.98401456       0.21657443
## texture_worst                0.365098245  0.34584228       0.22542941
## perimeter_worst              1.000000000  0.97757809       0.23677460
## area_worst                   0.977578091  1.00000000       0.20914533
## smoothness_worst             0.236774604  0.20914533       1.00000000
## compactness_worst            0.529407690  0.43829628       0.56818652
## concavity_worst              0.618344080  0.54333053       0.51852329
## concave_points_worst         0.816322102  0.74741880       0.54769090
## symmetry_worst               0.269492769  0.20914551       0.49383833
## fractal_dimension_worst      0.138956862  0.07964703       0.61762419
##                          compactness_worst concavity_worst concave_points_worst
## radius_mean                     0.41346282      0.52691146            0.7442142
## texture_mean                    0.27782959      0.30102522            0.2953158
## perimeter_mean                  0.45577423      0.56387926            0.7712408
## area_mean                       0.39041031      0.51260592            0.7220166
## smoothness_mean                 0.47246844      0.43492571            0.5030534
## compactness_mean                0.86580904      0.81627525            0.8155732
## concavity_mean                  0.75496802      0.88410264            0.8613230
## concave_points_mean             0.66745368      0.75239950            0.9101553
## symmetry_mean                   0.47320001      0.43372101            0.4302966
## fractal_dimension_mean          0.45879816      0.34623388            0.1753254
## radius_se                       0.28710317      0.38058463            0.5310623
## texture_se                     -0.09243935     -0.06895622           -0.1196375
## perimeter_se                    0.34191945      0.41889882            0.5548972
## area_se                         0.28325654      0.38510014            0.5381663
## smoothness_se                  -0.05555814     -0.05829839           -0.1020068
## compactness_se                  0.67878035      0.63914670            0.4832083
## concavity_se                    0.48485780      0.66256413            0.4404723
## concave_points_se               0.45288838      0.54959238            0.6024496
## symmetry_se                     0.06025488      0.03711905           -0.0304134
## fractal_dimension_se            0.39015884      0.37997466            0.2152040
## radius_worst                    0.47582004      0.57397471            0.7874239
```

```
## texture_worst                  0.36083234      0.36836561           0.3597546
## perimeter_worst                0.52940769      0.61834408           0.8163221
## area_worst                     0.43829628      0.54333053           0.7474188
## smoothness_worst               0.56818652      0.51852329           0.5476909
## compactness_worst              1.00000000      0.89226090           0.8010804
## concavity_worst                0.89226090      1.00000000           0.8554339
## concave_points_worst           0.80108036      0.85543386           1.0000000
## symmetry_worst                 0.61444050      0.53251973           0.5025285
## fractal_dimension_worst        0.81045486      0.68651092           0.5111141
##                          symmetry_worst fractal_dimension_worst
## radius_mean                  0.16395333              0.007065886
## texture_mean                 0.10500791              0.119205351
## perimeter_mean               0.18911504              0.051018530
## area_mean                    0.14356991              0.003737597
## smoothness_mean              0.39430948              0.499316369
## compactness_mean             0.51022343              0.687382323
## concavity_mean               0.40946413              0.514929891
## concave_points_mean          0.37574415              0.368661134
## symmetry_mean                0.69982580              0.438413498
## fractal_dimension_mean       0.33401868              0.767296779
## radius_se                    0.09454283              0.049559432
## texture_se                  -0.12821476             -0.045654569
## perimeter_se                 0.10993043              0.085432572
## area_se                      0.07412629              0.017539295
## smoothness_se               -0.10734210              0.101480315
## compactness_se               0.27787843              0.590972763
## concavity_se                 0.19778782              0.439329269
## concave_points_se            0.14311567              0.310654551
## symmetry_se                  0.38940248              0.078079476
## fractal_dimension_se         0.11109396              0.591328066
## radius_worst                 0.24352920              0.093491979
## texture_worst                0.23302746              0.219122425
## perimeter_worst              0.26949277              0.138956862
## area_worst                   0.20914551              0.079647034
## smoothness_worst             0.49383833              0.617624192
## compactness_worst            0.61444050              0.810454856
## concavity_worst              0.53251973              0.686510921
## concave_points_worst         0.50252849              0.511114146
## symmetry_worst               1.00000000              0.537848206
## fractal_dimension_worst      0.53784821              1.000000000
```

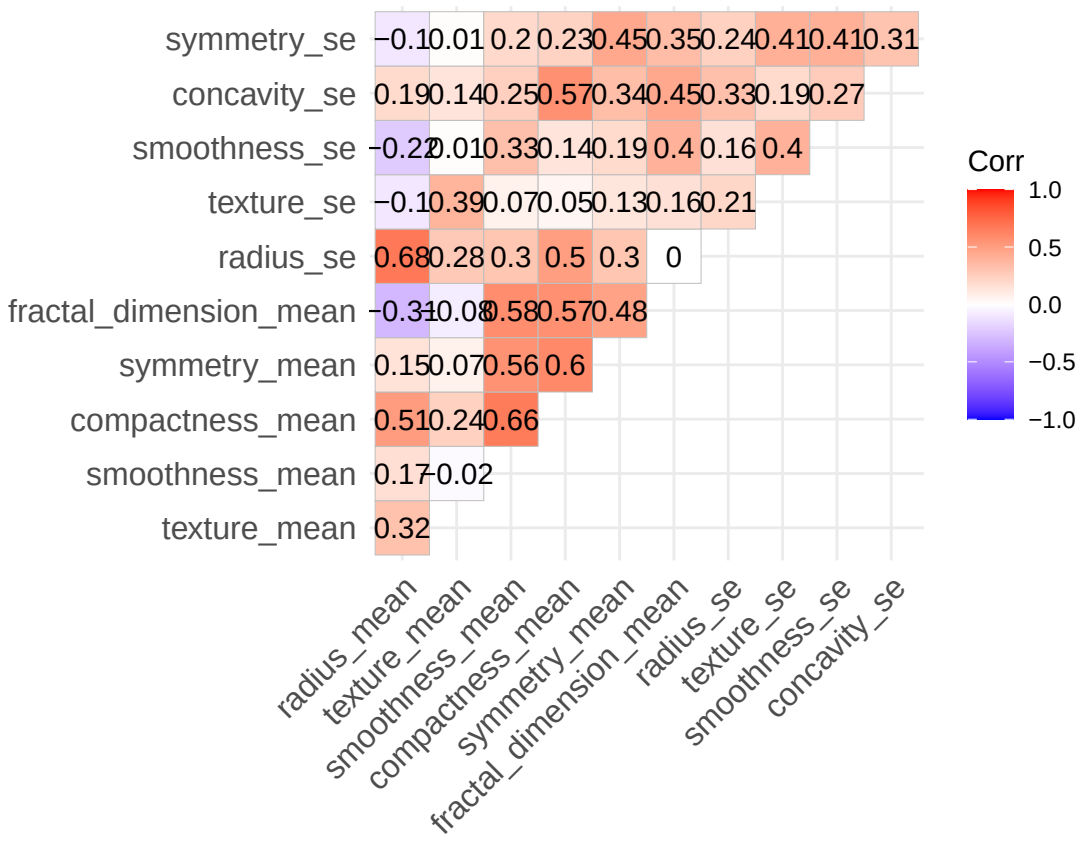
```
ggcorrplot(corr, type = "upper")
```




```
#if two variables have correlation > 0.7, drop one of them
X = stand_df %>%
  select(radius_mean, texture_mean, smoothness_mean, compactness_mean,
         symmetry_mean, fractal_dimension_mean, radius_se, texture_se,
         smoothness_se, concavity_se, symmetry_se)

#check the correlation after variable selection
corr_new = X %>% cor()

ggcorrplot(corr_new, type = "upper", lab = TRUE)
```



Logistic model

```
logdata = cbind.data.frame(y, X)
log_model = glm(y ~ ., family = binomial(link = "logit"),data = logdata)
summary(log_model)
```

```
##
## Call:
## glm(formula = y ~ ., family = binomial(link = "logit"), data = logdata)
##
## Deviance Residuals:
##      Min        1Q    Median        3Q       Max
## -2.16574  -0.12718  -0.02154   0.01963   2.97544
##
## Coefficients:
##                          Estimate Std. Error z value Pr(>|z|)
## (Intercept)               -1.0076     0.2706  -3.724 0.000196 ***
## radius_mean                3.7164     0.8087   4.595 4.32e-06 ***
## texture_mean               2.0204     0.3194   6.325 2.53e-10 ***
## smoothness_mean            1.4774     0.4478   3.299 0.000969 ***
## compactness_mean           0.7829     0.6409   1.222 0.221849
## symmetry_mean              0.9352     0.3487   2.682 0.007320 **
## fractal_dimension_mean    -0.3741     0.5950  -0.629 0.529550
## radius_se                  1.7219     0.6012   2.864 0.004180 **
## texture_se                -0.8036     0.3524  -2.280 0.022594 *
```

```
## smoothness_se           -0.4485     0.3147  -1.425 0.154059
## concavity_se             0.3509     0.2751   1.275 0.202151
## symmetry_se             -0.7307     0.3331  -2.193 0.028282 *
## ---
## 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: 157.74  on 557  degrees of freedom
## AIC: 181.74
##
## Number of Fisher Scoring iterations: 8
```