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CAC-2

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suppressMessages(library(tidyverse)) # data manipulation and plots  
suppressMessages(library(funModeling)) # overview stats  
library(magrittr) # to use pipes

##   
## Attaching package: 'magrittr'

## The following object is masked from 'package:purrr':  
##   
## set\_names

## The following object is masked from 'package:tidyr':  
##   
## extract

library(skimr) # to get a quick summary table  
library(caret) # to create the partition for training/test datasets

##   
## Attaching package: 'caret'

## The following object is masked from 'package:survival':  
##   
## cluster

## The following object is masked from 'package:purrr':  
##   
## lift

options(scipen = 999) # turn off scientific notation for numbers  
options(repr.plot.width=12, repr.plot.height=8) # set universal plot size

# read the file in  
df <- read.csv('insurance.csv')  
  
# denote factor variables  
df$sex <- factor(df$sex)  
df$smoker <- factor(df$smoker)  
df$region <- factor(df$region)  
df$children <- factor(df$children)

# check for missing values  
df %>%  
 is.na() %>%  
 sum()

## [1] 0

# check data types  
df %>%  
 str()

## 'data.frame': 1338 obs. of 7 variables:  
## $ age : int 19 18 28 33 32 31 46 37 37 60 ...  
## $ sex : Factor w/ 2 levels "female","male": 1 2 2 2 2 1 1 1 2 1 ...  
## $ bmi : num 27.9 33.8 33 22.7 28.9 ...  
## $ children: Factor w/ 6 levels "0","1","2","3",..: 1 2 4 1 1 1 2 4 3 1 ...  
## $ smoker : Factor w/ 2 levels "no","yes": 2 1 1 1 1 1 1 1 1 1 ...  
## $ region : Factor w/ 4 levels "northeast","northwest",..: 4 3 3 2 2 3 3 2 1 2 ...  
## $ charges : num 16885 1726 4449 21984 3867 ...

skim(df)

Data summary

|  |  |
| --- | --- |
| Name | df |
| Number of rows | 1338 |
| Number of columns | 7 |
| \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |  |
| Column type frequency: |  |
| factor | 4 |
| numeric | 3 |
| \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |  |
| Group variables | None |

**Variable type: factor**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| skim\_variable | n\_missing | complete\_rate | ordered | n\_unique | top\_counts |
| sex | 0 | 1 | FALSE | 2 | mal: 676, fem: 662 |
| children | 0 | 1 | FALSE | 6 | 0: 574, 1: 324, 2: 240, 3: 157 |
| smoker | 0 | 1 | FALSE | 2 | no: 1064, yes: 274 |
| region | 0 | 1 | FALSE | 4 | sou: 364, nor: 325, sou: 325, nor: 324 |

**Variable type: numeric**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| skim\_variable | n\_missing | complete\_rate | mean | sd | p0 | p25 | p50 | p75 | p100 | hist |
| age | 0 | 1 | 39.21 | 14.05 | 18.00 | 27.00 | 39.00 | 51.00 | 64.00 | ▇▅▅▆▆ |
| bmi | 0 | 1 | 30.66 | 6.10 | 15.96 | 26.30 | 30.40 | 34.69 | 53.13 | ▂▇▇▂▁ |
| charges | 0 | 1 | 13270.42 | 12110.01 | 1121.87 | 4740.29 | 9382.03 | 16639.91 | 63770.43 | ▇▂▁▁▁ |

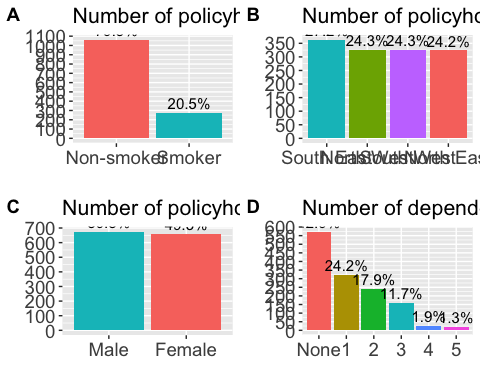
figsize <- options(repr.plot.width=12, repr.plot.height=12) # set plot size for this plot   
  
# Smoker count plot  
smoker <- df %>%  
 ggplot(aes(x=smoker, fill=smoker)) +  
 geom\_bar(show.legend = FALSE) +  
 # add percentages on top of bars  
 geom\_text(  
 stat='count',  
 aes(label=paste0(round(after\_stat(prop\*100), digits=1), "%"),group=1),  
 vjust=-0.4,  
 size=4  
 ) +  
 # add labels  
 labs(  
 x = "",  
 y = "",  
 title = "Number of policyholders by smoking"  
 ) +  
 # rename x-ticks  
 scale\_x\_discrete(  
 labels = c("no" = "Non-smoker", "yes" = "Smoker")  
 ) +  
 # adjust y-ticks  
 scale\_y\_continuous(  
 breaks=seq(0,2000,100)  
 ) +  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text.x = element\_text(size=14),  
 axis.text.y = element\_text(size=14)  
 )

# Region count plot  
region <- df %>%  
 ggplot(aes(x=forcats::fct\_infreq(region), fill=region)) +  
 geom\_bar(show.legend = FALSE) +  
 # add percentages on top of bars  
 geom\_text(  
 stat='count',  
 aes(label = paste0(round(after\_stat(prop\*100), digits=1), "%"), group=1),  
 vjust=-0.4,  
 size=4  
 ) +  
 # add labels  
 labs(  
 x = "",  
 y = "",  
 title = "Number of policyholders by region"  
 ) +  
 # rename x-ticks  
 scale\_x\_discrete(  
 labels = c("northeast" = "North East", "northwest" = "North West",  
 "southeast" = "South East", "southwest" = "South West")  
 ) +  
 # adjust ticks  
 scale\_y\_continuous(  
 breaks=seq(0,350,50)  
 ) +  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text.x = element\_text(size=14),  
 axis.text.y = element\_text(size=14)  
 )

# Sex count plot  
sex <- df %>%  
 ggplot(aes(x=forcats::fct\_infreq(sex), fill=sex)) +  
 geom\_bar(show.legend = FALSE) +  
 # add percentages on top of bars  
 geom\_text(  
 stat='count',  
 aes(  
 label=paste0(round(after\_stat(prop\*100), digits=1), "%"), group=1),  
 vjust=-0.4,  
 size=4  
 ) +  
 # add labels  
 labs(  
 x = "",  
 y = "",  
 title = "Number of policyholders by sex",  
 fill = "Sex"  
 ) +  
 # rename x-ticks  
 scale\_x\_discrete(  
 labels = c("male" = "Male", "female" = "Female")  
 ) +  
 # adjust y-ticks  
 scale\_y\_continuous(  
 breaks=seq(0,700,100)  
 ) +  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text.x = element\_text(size=14),  
 axis.text.y = element\_text(size=14)  
 )

# Children count plot  
children <- df %>%  
 ggplot(aes(x=forcats::fct\_infreq(children), fill=children)) +  
 geom\_bar(show.legend = FALSE) +  
 # add percentages  
 geom\_text(  
 stat='count',  
 aes(label=paste0(round(after\_stat(prop\*100), digits=1), "%"), group=1),  
 vjust=-0.4,  
 size=4  
 ) +  
 # add labels  
 labs(  
 x = "",  
 y = "",  
 title = "Number of dependents per policy"  
 ) +  
 # rename x-ticks  
 scale\_x\_discrete(  
 labels = c("0" = "None")  
 ) +  
 # adjust y-ticks  
 scale\_y\_continuous(  
 breaks=seq(0,600,50)  
 ) +  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text.x = element\_text(size=14),  
 axis.text.y = element\_text(size=14)  
 )

# Plot grid  
cowplot::plot\_grid(  
 smoker, region, sex, children,  
 labels="AUTO",  
 ncol = 2,  
 nrow = 2  
 )



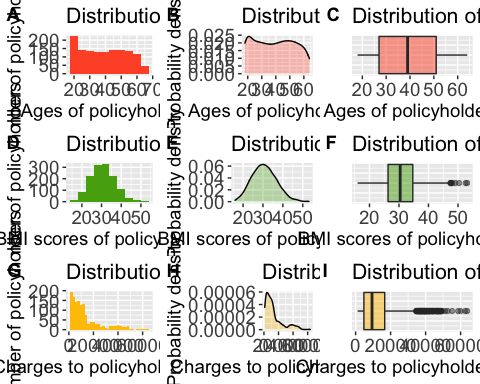
options(figsize)

figsize <- options(repr.plot.width=20, repr.plot.height=16)  
  
# Age distribution  
age\_hist <- df %>%  
 ggplot(aes(x=age))+  
 geom\_histogram(  
 binwidth = 5,  
 show.legend = FALSE,  
 fill="#ff5733"  
 )+  
 labs(  
 x = "Ages of policyholders",  
 y = "Number of policyholders",  
 title = "Distribution of ages"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
age\_dens <- df %>%  
 ggplot(aes(x=age)) +  
 geom\_density(  
 alpha=.3,  
 fill="#ff5733"  
 )+  
 labs(  
 x = "Ages of policyholders",  
 y = "Probability density",  
 title = "Distribution of ages"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
age\_box <- df %>%  
 ggplot(aes(y=age)) +  
 geom\_boxplot(  
 alpha=.5,  
 fill="#ff5733"  
 )+  
 coord\_flip() +  
 theme(  
 axis.text.y = element\_blank(),  
 axis.ticks.y = element\_blank()  
 )+  
 labs(  
 y = "Ages of policyholders",  
 x = "",  
 title = "Distribution of ages"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

# BMI distribution  
bmi\_hist <- df %>%  
 ggplot(aes(x=bmi))+  
 geom\_histogram(  
 binwidth = 4,  
 show.legend = FALSE,  
 fill = "#55ab11"  
 )+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Number of policyholders",  
 title = "Distribution of BMI scores"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_dens <- df %>%  
 ggplot(aes(x=bmi)) +  
 geom\_density(  
 alpha=.3,  
 fill="#55ab11"  
 )+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Probability density",  
 title = "Distribution of BMI scores"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_box <- df %>%  
 ggplot(aes(y=bmi)) +  
 geom\_boxplot(  
 alpha=.5,  
 fill="#55ab11"  
 )+  
 coord\_flip() +  
 theme(  
 axis.text.y = element\_blank(),  
 axis.ticks.y = element\_blank()  
 )+  
 labs(  
 y = "BMI scores of policyholders",  
 x = "",  
 title = "Distribution of BMI scores"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

# Charges distribution  
charges\_hist <- df %>%  
 ggplot(aes(x=charges)) +  
 geom\_histogram(  
 binwidth = 2000,  
 show.legend = FALSE,  
 fill = "#FFC300"  
 )+  
 labs(  
 x = "Charges to policyholders ($)",  
 y = "Number of policyholders",  
 title = "Distribution of medical charges"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
charges\_dens <- df %>%  
 ggplot(  
 aes(x=charges)  
 ) +  
 geom\_density(  
 alpha=.3,  
 fill="#FFC300"  
 ) +  
 labs(  
 x = "Charges to policyholders ($)",  
 y = "Probability density",  
 title = "Distribution of medical charges"  
 ) +  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
charges\_box <- df %>%  
 ggplot(aes(y=charges))+  
 geom\_boxplot(  
 alpha=.5,  
 fill="#FFC300"  
 )+  
 coord\_flip()+  
 # remove ticks from y-axis  
 theme(  
 axis.text.y = element\_blank(),  
 axis.ticks.y = element\_blank()  
 )+  
 labs(  
 y = "Charges to policyholders ($)",  
 x = "",  
 title = "Distribution of medical charges"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

cowplot::plot\_grid(  
 age\_hist, age\_dens, age\_box,  
 bmi\_hist, bmi\_dens, bmi\_box,  
 charges\_hist, charges\_dens, charges\_box,  
 labels="AUTO",  
 ncol = 3,  
 nrow = 3  
 )

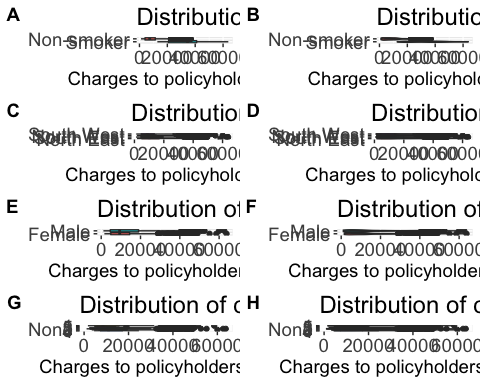


options(figsize)

figsize <- options(repr.plot.width=20, repr.plot.height=26)  
  
# Boxplots  
chargesBysmoker <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(smoker, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=smoker  
 )  
 ) +  
 geom\_boxplot(show.legend = FALSE) +  
 coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges by smoking"  
 )+  
 scale\_x\_discrete(  
 labels = c("no" = "Non-smoker", "yes" = "Smoker")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
   
chargesByregion <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(region, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=region  
 )  
 ) +  
 geom\_boxplot(show.legend = FALSE) +  
 coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges by region"  
 )+  
 scale\_x\_discrete(  
 labels = c("northeast" = "North East", "northwest" = "North West",  
 "southeast" = "South East", "southwest" = "South West")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
chargesBychildren <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(children, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=children  
 )  
 ) +  
 geom\_boxplot(show.legend = FALSE) +  
 coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges by dependents"  
 )+  
 scale\_x\_discrete(  
 labels = c("0" = "None")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
chargesBysex <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(sex, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=sex  
 )  
 ) +  
 geom\_boxplot(show.legend = FALSE) +  
 coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges by sex"  
 )+  
 scale\_x\_discrete(  
 labels = c("male" = "Male", "female" = "Female")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

# Density plots with medians  
densityBySmoker <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(smoker, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=smoker  
 )  
 ) +  
 geom\_violin(show.legend = FALSE) +  
 geom\_boxplot(  
 width=0.1,  
 show.legend = FALSE  
 )+  
 coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges with density by smoking"  
 )+  
 scale\_x\_discrete(  
 labels = c("no" = "Non-smoker", "yes" = "Smoker")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
densityByRegion <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(region, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=region  
 )  
 ) +  
 geom\_violin(show.legend = FALSE) +  
 geom\_boxplot(  
 width=0.1,  
 show.legend = FALSE  
 )+ coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges with density by region"  
 )+  
 scale\_x\_discrete(labels = c("northeast" = "North East", "northwest" = "North West",  
 "southeast" = "South East", "southwest" = "South West")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
densityBySex <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(sex, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=sex  
 )  
 ) +  
 geom\_violin(show.legend = FALSE) +  
 geom\_boxplot(  
 width=0.1,  
 show.legend = FALSE  
 )+ coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges with density by sex"  
 )+  
 scale\_x\_discrete(  
 labels = c("male" = "Male", "female" = "Female")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
densityByChildren <- df %>%  
 ggplot(  
 aes(  
 x=forcats::fct\_reorder(children, charges, .fun=median, .desc=TRUE),  
 y=charges,  
 fill=children  
 )  
 ) +  
 geom\_violin(show.legend = FALSE) +  
 geom\_boxplot(  
 width=0.1,  
 show.legend = FALSE  
 )+ coord\_flip() +  
 labs(  
 x = "",  
 y = "Charges to policyholders ($)",  
 title = "Distribution of charges with density by dependents"  
 )+  
 scale\_x\_discrete(  
 labels = c("0" = "None")  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

# Plot grid of all plots  
cowplot::plot\_grid(  
 chargesBysmoker, densityBySmoker,  
 chargesByregion, densityByRegion,  
 chargesBysex, densityBySex,  
 chargesBychildren, densityByChildren,  
 labels="AUTO",  
 ncol = 2,  
 nrow = 4  
)

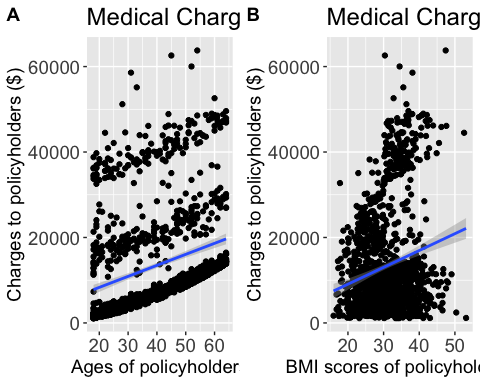


options(figsize)

figsize <- options(repr.plot.width=12, repr.plot.height=8)  
  
age\_scatter <- df %>%  
 ggplot(aes(x=age, y=charges)) +  
 geom\_point()+  
 # add a linear regression line  
 geom\_smooth(method='lm')+  
 labs(  
 x = "Ages of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder Age"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_scatter <- df %>%  
 ggplot(aes(x=bmi, y=charges)) +  
 geom\_point()+  
 # add a linear regression line  
 geom\_smooth(method='lm')+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder BMI"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

cowplot::plot\_grid(  
 age\_scatter, bmi\_scatter,  
 labels="AUTO",  
 ncol = 2,  
 nrow = 1  
 )

## `geom\_smooth()` using formula 'y ~ x'  
## `geom\_smooth()` using formula 'y ~ x'



options(figsize)

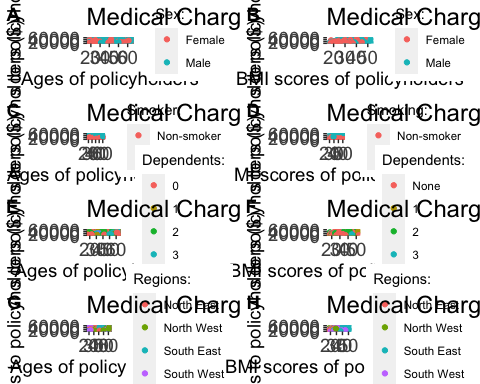
figsize <- options(repr.plot.width=20, repr.plot.height=22)  
  
# by sex  
age\_scatter\_sex <- df %>%  
 ggplot(aes(x=age, y=charges, color=sex)) +  
 geom\_point()+  
 labs(  
 x = "Ages of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder Age by Sex",  
 color = "Sex:"  
 )+  
 scale\_color\_hue(labels = c("male" = "Male", "female" = "Female"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_scatter\_sex <- df %>%  
 ggplot(aes(x=bmi, y=charges, color=sex)) +  
 geom\_point()+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder BMI by Sex",  
 color = "Sex:"  
 )+  
 scale\_color\_hue(labels = c("male" = "Male", "female" = "Female"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

#by smoker  
age\_scatter\_smoker <- df %>%  
 ggplot(aes(x=age, y=charges, color=smoker)) +  
 geom\_point()+  
 labs(  
 x = "Ages of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder Age by Smoking",  
 color = "Smoker:"  
 )+  
 scale\_color\_hue(labels = c("no" = "Non-smoker", "yes" = "Smoker"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_scatter\_smoker <- df %>%  
 ggplot(aes(x=bmi, y=charges, color=smoker)) +  
 geom\_point()+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder BMI by Smoking",  
 color = "Smoking:"  
 )+  
 scale\_color\_hue(labels = c("no" = "Non-smoker", "yes" = "Smoker"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

#by children  
age\_scatter\_kids <- df %>%  
 ggplot(aes(x=age, y=charges, color=children)) +  
 geom\_point()+  
 labs(  
 x = "Ages of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder Age by Dependents",  
 color = "Dependents:"  
 )+  
 scale\_color\_hue(labels = c("no" = "Non-smoker", "yes" = "Smoker"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_scatter\_kids <- df %>%  
 ggplot(aes(x=bmi, y=charges, color=children)) +  
 geom\_point()+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder BMI by Dependents",  
 color = "Dependents:"  
 )+  
 scale\_color\_hue(labels = c("0" = "None"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

#by region  
age\_scatter\_region <- df %>%  
 ggplot(aes(x=age, y=charges, color=region)) +  
 geom\_point()+  
 labs(  
 x = "Ages of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder Age by Region",  
 color = "Regions:"  
 )+  
 scale\_color\_hue(labels = c("northeast" = "North East", "northwest" = "North West",  
 "southeast" = "South East", "southwest" = "South West"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
bmi\_scatter\_region <- df %>%  
 ggplot(aes(x=bmi, y=charges, color=region)) +  
 geom\_point()+  
 labs(  
 x = "BMI scores of policyholders",  
 y = "Charges to policyholders ($)",  
 title = "Medical Charges vs Policyholder BMI by Regions",  
 color = "Regions:"  
 )+  
 scale\_color\_hue(labels = c("northeast" = "North East", "northwest" = "North West",  
 "southeast" = "South East", "southwest" = "South West"))+  
 guides(fill=FALSE)+  
 # resize text  
 theme(  
 plot.title = element\_text(size=18),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

# make a grid  
cowplot::plot\_grid(  
 age\_scatter\_sex, bmi\_scatter\_sex,  
 age\_scatter\_smoker, bmi\_scatter\_smoker,  
 age\_scatter\_kids, bmi\_scatter\_kids,  
 age\_scatter\_region, bmi\_scatter\_region,  
 labels="AUTO",  
 ncol = 2,  
 nrow = 4  
 )



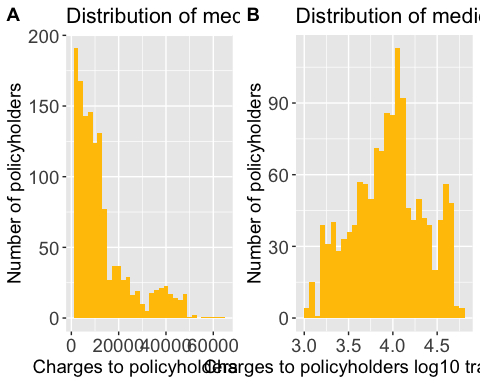
options(figsize)

## Multiple linear regression

charges\_hist <- df %>%  
 ggplot(  
 aes(x=charges)  
 ) +  
 geom\_histogram(  
 binwidth = 2000,  
 show.legend = FALSE,  
 fill = "#FFC300"  
 )+  
 labs(  
 x = "Charges to policyholders ($)",  
 y = "Number of policyholders",  
 title = "Distribution of medical charges"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )  
  
charges\_hist\_log10 <- df %>%  
 ggplot(  
 aes(x=log10(charges))  
 ) +  
 geom\_histogram(  
 show.legend = FALSE,  
 fill = "#FFC300"  
 )+  
 labs(  
 x = "Charges to policyholders log10 transformed",  
 y = "Number of policyholders",  
 title = "Distribution of medical charges after log10 transform"  
 )+  
 # resize text  
 theme(  
 plot.title = element\_text(size=16),  
 axis.text = element\_text(size=14),  
 axis.title = element\_text(size=14)  
 )

cowplot::plot\_grid(  
 charges\_hist, charges\_hist\_log10,  
 labels="AUTO",  
 ncol = 2,  
 nrow = 1  
 )

## `stat\_bin()` using `bins = 30`. Pick better value with `binwidth`.



## Split the dataset and train the model

# log10 transform of response variable   
df$logCharges<- log10(df$charges)  
  
drops <- c("charges")  
df[ , !(names(df) %in% drops)]

## age sex bmi children smoker region logCharges  
## 1 19 female 27.900 0 yes southwest 4.227499  
## 2 18 male 33.770 1 no southeast 3.236928  
## 3 28 male 33.000 3 no southeast 3.648308  
## 4 33 male 22.705 0 no northwest 4.342116  
## 5 32 male 28.880 0 no northwest 3.587358  
## 6 31 female 25.740 0 no southeast 3.574797  
## 7 46 female 33.440 1 no southeast 3.915958  
## 8 37 female 27.740 3 no northwest 3.862221  
## 9 37 male 29.830 2 no northeast 3.806615  
## 10 60 female 25.840 0 no northwest 4.461245  
## 11 25 male 26.220 0 no northeast 3.434780  
## 12 62 female 26.290 0 yes southeast 4.444181  
## 13 23 male 34.400 0 no southwest 3.261701  
## 14 56 female 39.820 0 no southeast 4.044960  
## 15 27 male 42.130 0 yes southeast 4.597824  
## 16 19 male 24.600 1 no southwest 3.264165  
## 17 52 female 30.780 1 no northeast 4.033317  
## 18 23 male 23.845 0 no northeast 3.379337  
## 19 56 male 40.300 0 no southwest 4.025404  
## 20 30 male 35.300 0 yes southwest 4.566290  
## 21 60 female 36.005 0 no northeast 4.121522  
## 22 30 female 32.400 1 no southwest 3.618020  
## 23 18 male 34.100 0 no southeast 3.055765  
## 24 34 female 31.920 1 yes northeast 4.576363  
## 25 37 male 28.025 2 no northwest 3.792665  
## 26 59 female 27.720 3 no southeast 4.146163  
## 27 63 female 23.085 0 no northeast 4.159923  
## 28 55 female 32.775 2 no northwest 4.088796  
## 29 23 male 17.385 1 no northwest 3.443293  
## 30 31 male 36.300 2 yes southwest 4.587834  
## 31 22 male 35.600 0 yes southwest 4.551274  
## 32 18 female 26.315 0 no northeast 3.342065  
## 33 19 female 28.600 5 no southwest 3.670969  
## 34 63 male 28.310 0 no northwest 4.138937  
## 35 28 male 36.400 1 yes southwest 4.709224  
## 36 19 male 20.425 0 no northwest 3.210969  
## 37 62 female 32.965 3 no northwest 4.193464  
## 38 26 male 20.800 0 no southwest 3.362162  
## 39 35 male 36.670 1 yes northeast 4.599602  
## 40 60 male 39.900 0 yes southwest 4.682807  
## 41 24 female 26.600 0 no northeast 3.483739  
## 42 31 female 36.630 2 no southeast 3.694584  
## 43 41 male 21.780 1 no southeast 3.797439  
## 44 37 female 30.800 2 no southeast 3.800288  
## 45 38 male 37.050 1 no northeast 3.783880  
## 46 55 male 37.300 0 no southwest 4.314505  
## 47 18 female 38.665 2 no northeast 3.530629  
## 48 28 female 34.770 0 no northwest 3.551074  
## 49 60 female 24.530 0 no southeast 4.101400  
## 50 36 male 35.200 1 yes southeast 4.587814  
## 51 18 female 35.625 0 no northeast 3.344614  
## 52 21 female 33.630 2 no northwest 3.553862  
## 53 48 male 28.000 1 yes southwest 4.372328  
## 54 36 male 34.430 0 yes southeast 4.576832  
## 55 40 female 28.690 3 no northwest 3.906318  
## 56 58 male 36.955 2 yes northwest 4.676662  
## 57 58 female 31.825 2 no northeast 4.133774  
## 58 18 male 31.680 2 yes southeast 4.535334  
## 59 53 female 22.880 1 yes southeast 4.366326  
## 60 34 female 37.335 2 no northwest 3.777392  
## 61 43 male 27.360 3 no northeast 3.934812  
## 62 25 male 33.660 4 no southeast 3.653662  
## 63 64 male 24.700 1 no northwest 4.479527  
## 64 28 female 25.935 1 no northwest 3.616333  
## 65 20 female 22.420 0 yes northwest 4.167664  
## 66 19 female 28.900 0 no southwest 3.241351  
## 67 61 female 39.100 2 no southwest 4.153360  
## 68 40 male 26.315 1 no northwest 3.805459  
## 69 40 female 36.190 0 no southeast 3.772329  
## 70 28 male 23.980 3 yes southeast 4.247068  
## 71 27 female 24.750 0 yes southeast 4.219526  
## 72 31 male 28.500 5 no northeast 3.832474  
## 73 53 female 28.100 3 no southwest 4.069732  
## 74 58 male 32.010 1 no southeast 4.077245  
## 75 44 male 27.400 2 no southwest 3.888003  
## 76 57 male 34.010 0 no northwest 4.055251  
## 77 29 female 29.590 1 no southeast 3.596313  
## 78 21 male 35.530 0 no southeast 3.185392  
## 79 22 female 39.805 0 no northeast 3.440125  
## 80 41 female 32.965 0 no northwest 3.817633  
## 81 31 male 26.885 1 no northeast 3.647502  
## 82 45 female 38.285 0 no northeast 3.899563  
## 83 22 male 37.620 1 yes southeast 4.570136  
## 84 48 female 41.230 4 no northwest 4.042720  
## 85 37 female 34.800 2 yes southwest 4.600281  
## 86 45 male 22.895 2 yes northwest 4.324253  
## 87 57 female 31.160 0 yes northwest 4.639277  
## 88 56 female 27.200 0 no southwest 4.044272  
## 89 46 female 27.740 0 no northwest 3.904535  
## 90 55 female 26.980 0 no northwest 4.044641  
## 91 21 female 39.490 0 no southeast 3.306848  
## 92 53 female 24.795 1 no northwest 4.039102  
## 93 59 male 29.830 3 yes northeast 4.479790  
## 94 35 male 34.770 2 no northwest 3.758079  
## 95 64 female 31.300 2 yes southwest 4.674779  
## 96 28 female 37.620 1 no southeast 3.575982  
## 97 54 female 30.800 3 no southwest 4.082976  
## 98 55 male 38.280 0 no southeast 4.009718  
## 99 56 male 19.950 0 yes northeast 4.350493  
## 100 38 male 19.300 0 yes southwest 4.199226  
## 101 41 female 31.600 0 no southwest 3.791419  
## 102 30 male 25.460 0 no northeast 3.561708  
## 103 18 female 30.115 0 no northeast 4.329293  
## 104 61 female 29.920 3 yes southeast 4.490551  
## 105 34 female 27.500 1 no southwest 3.699305  
## 106 20 male 28.025 1 yes northwest 4.244534  
## 107 19 female 28.400 1 no southwest 3.367639  
## 108 26 male 30.875 2 no northwest 3.588530  
## 109 29 male 27.940 0 no southeast 3.457446  
## 110 63 male 35.090 0 yes southeast 4.672611  
## 111 54 male 33.630 1 no northwest 4.034438  
## 112 55 female 29.700 2 no southwest 4.074866  
## 113 37 male 30.800 0 no southwest 3.667150  
## 114 21 female 35.720 0 no northwest 3.381067  
## 115 52 male 32.205 3 no northeast 4.060256  
## 116 60 male 28.595 0 no northeast 4.480869  
## 117 58 male 49.060 0 no southeast 4.056193  
## 118 29 female 27.940 1 yes southeast 4.281210  
## 119 49 female 27.170 0 no southeast 3.934566  
## 120 37 female 23.370 2 no northwest 3.825194  
## 121 44 male 37.100 2 no southwest 3.888760  
## 122 18 male 23.750 0 no northeast 3.231883  
## 123 20 female 28.975 0 no northwest 3.353623  
## 124 44 male 31.350 1 yes northeast 4.597218  
## 125 47 female 33.915 3 no northwest 4.004966  
## 126 26 female 28.785 0 no northeast 3.529610  
## 127 19 female 28.300 0 yes southwest 4.232515  
## 128 52 female 37.400 0 no southwest 3.983831  
## 129 32 female 17.765 2 yes northwest 4.515002  
## 130 38 male 34.700 2 no southwest 3.784075  
## 131 59 female 26.505 0 no northeast 4.107734  
## 132 61 female 22.040 0 no northeast 4.134061  
## 133 53 female 35.900 2 no southwest 4.047803  
## 134 19 male 25.555 0 no northwest 3.212870  
## 135 20 female 28.785 0 no northeast 3.390442  
## 136 22 female 28.050 0 no southeast 3.333585  
## 137 19 male 34.100 0 no southwest 3.100867  
## 138 22 male 25.175 0 no northwest 3.310839  
## 139 54 female 31.900 3 no southeast 4.436524  
## 140 22 female 36.000 0 no southwest 3.335805  
## 141 34 male 22.420 2 no northeast 4.437368  
## 142 26 male 32.490 1 no northeast 3.542894  
## 143 34 male 25.300 2 yes southeast 4.278124  
## 144 29 male 29.735 2 no northwest 4.259065  
## 145 30 male 28.690 3 yes northwest 4.316934  
## 146 29 female 38.830 3 no southeast 3.710816  
## 147 46 male 30.495 3 yes northwest 4.609814  
## 148 51 female 37.730 1 no southeast 3.994652  
## 149 53 female 37.430 1 no northwest 4.039798  
## 150 19 male 28.400 1 no southwest 3.265412  
## 151 35 male 24.130 1 no northwest 3.709712  
## 152 48 male 29.700 0 no southeast 3.891517  
## 153 32 female 37.145 3 no northeast 3.801702  
## 154 42 female 23.370 0 yes northeast 4.300264  
## 155 40 female 25.460 1 no northeast 3.849861  
## 156 44 male 39.520 0 no northwest 3.841904  
## 157 48 male 24.420 0 yes southeast 4.326821  
## 158 18 male 25.175 0 yes northeast 4.190841  
## 159 30 male 35.530 0 yes southeast 4.567617  
## 160 50 female 27.830 3 no southeast 4.295554  
## 161 42 female 26.600 0 yes northwest 4.329372  
## 162 18 female 36.850 0 yes southeast 4.558102  
## 163 54 male 39.600 1 no southwest 4.019139  
## 164 32 female 29.800 2 no southwest 3.711987  
## 165 37 male 29.640 0 no northwest 3.701408  
## 166 47 male 28.215 4 no northeast 4.017329  
## 167 20 female 37.000 5 no southwest 3.684004  
## 168 32 female 33.155 3 no northwest 3.787375  
## 169 19 female 31.825 1 no northwest 3.434454  
## 170 27 male 18.905 3 no northeast 3.683759  
## 171 63 male 41.470 0 no southeast 4.127279  
## 172 49 male 30.300 0 no southwest 3.909378  
## 173 18 male 15.960 0 no northeast 3.229118  
## 174 35 female 34.800 1 no southwest 3.719832  
## 175 24 female 33.345 0 no northwest 3.455673  
## 176 63 female 37.700 0 yes southwest 4.688637  
## 177 38 male 27.835 2 no northwest 3.809954  
## 178 54 male 29.200 1 no southwest 4.018538  
## 179 46 female 28.900 2 no southwest 3.945630  
## 180 41 female 33.155 3 no northeast 3.931371  
## 181 58 male 28.595 0 no northwest 4.069516  
## 182 18 female 38.280 0 no southeast 3.212673  
## 183 22 male 19.950 3 no northeast 3.602648  
## 184 44 female 26.410 0 no northwest 3.870373  
## 185 44 male 30.690 2 no southeast 3.888260  
## 186 36 male 41.895 3 yes northeast 4.641011  
## 187 26 female 29.920 2 no southeast 3.600099  
## 188 30 female 30.900 3 no southwest 3.726373  
## 189 41 female 32.200 1 no southwest 3.830971  
## 190 29 female 32.110 2 no northwest 3.692222  
## 191 61 male 31.570 0 no southeast 4.098907  
## 192 36 female 26.200 0 no southwest 3.688764  
## 193 25 male 25.740 0 no southeast 3.329937  
## 194 56 female 26.600 1 no northwest 4.080783  
## 195 18 male 34.430 0 no southeast 3.055940  
## 196 19 male 30.590 0 no northwest 3.214728  
## 197 39 female 32.800 0 no southwest 3.752027  
## 198 45 female 28.600 2 no southeast 3.930278  
## 199 51 female 18.050 0 no northwest 3.984269  
## 200 64 female 39.330 0 no northeast 4.173230  
## 201 19 female 32.110 0 no northwest 3.328517  
## 202 48 female 32.230 1 no southeast 3.947980  
## 203 60 female 24.035 0 no northwest 4.114351  
## 204 27 female 36.080 0 yes southeast 4.569771  
## 205 46 male 22.300 0 no southwest 3.854130  
## 206 28 female 28.880 1 no northeast 3.637263  
## 207 59 male 26.400 0 no southeast 4.069790  
## 208 35 male 27.740 2 yes northeast 4.321890  
## 209 63 female 31.800 0 no southwest 4.142419  
## 210 40 male 41.230 1 no northeast 3.820209  
## 211 20 male 33.000 1 no southwest 3.296681  
## 212 40 male 30.875 4 no northwest 3.911835  
## 213 24 male 28.500 2 no northwest 3.548721  
## 214 34 female 26.730 1 no southeast 3.699212  
## 215 45 female 30.900 2 no southwest 3.930441  
## 216 41 female 37.100 2 no southwest 3.867572  
## 217 53 female 26.600 0 no northwest 4.015177  
## 218 27 male 23.100 0 no southeast 3.395105  
## 219 26 female 29.920 1 no southeast 3.530581  
## 220 24 female 23.210 0 no southeast 4.399358  
## 221 34 female 33.700 1 no southwest 3.700052  
## 222 53 female 33.250 0 no northeast 4.023865  
## 223 32 male 30.800 3 no southwest 3.720451  
## 224 19 male 34.800 0 yes southwest 4.541325  
## 225 42 male 24.640 0 yes southeast 4.290381  
## 226 55 male 33.880 3 no southeast 4.078717  
## 227 28 male 38.060 0 no southeast 3.429671  
## 228 58 female 41.910 0 no southeast 4.384306  
## 229 41 female 31.635 1 no northeast 3.866770  
## 230 47 male 25.460 2 no northeast 3.964978  
## 231 42 female 36.195 1 no northwest 3.871786  
## 232 59 female 27.830 3 no southeast 4.146168  
## 233 19 female 17.800 0 no southwest 3.237490  
## 234 59 male 27.500 1 no southwest 4.091098  
## 235 39 male 24.510 2 no northwest 3.826735  
## 236 40 female 22.220 2 yes southeast 4.288792  
## 237 18 female 26.730 0 no southeast 3.208379  
## 238 31 male 38.390 2 no southeast 3.649647  
## 239 19 male 29.070 0 yes northwest 4.239367  
## 240 44 male 38.060 1 no southeast 3.854468  
## 241 23 female 36.670 2 yes northeast 4.585592  
## 242 33 female 22.135 1 no northeast 3.728684  
## 243 55 female 26.800 1 no southwest 4.546051  
## 244 40 male 35.300 3 no southwest 3.857143  
## 245 63 female 27.740 0 yes northeast 4.470163  
## 246 54 male 30.020 0 no northwest 4.388749  
## 247 60 female 38.060 0 no southeast 4.102046  
## 248 24 male 35.860 0 no southeast 3.298183  
## 249 19 male 20.900 1 no southwest 3.262948  
## 250 29 male 28.975 1 no northeast 3.606441  
## 251 18 male 17.290 2 yes northeast 4.108208  
## 252 63 female 32.200 2 yes southwest 4.674910  
## 253 54 male 34.210 2 yes southeast 4.646019  
## 254 27 male 30.300 3 no southwest 3.629485  
## 255 50 male 31.825 0 yes northeast 4.613812  
## 256 55 female 25.365 3 no northeast 4.115522  
## 257 56 male 33.630 0 yes northwest 4.642674  
## 258 38 female 40.150 0 no southeast 3.732473  
## 259 51 male 24.415 4 no northwest 4.061456  
## 260 19 male 31.920 0 yes northwest 4.528278  
## 261 58 female 25.200 0 no southwest 4.073248  
## 262 20 female 26.840 1 yes southeast 4.232622  
## 263 52 male 24.320 3 yes northeast 4.395673  
## 264 19 male 36.955 0 yes northwest 4.558941  
## 265 53 female 38.060 3 no southeast 4.310969  
## 266 46 male 42.350 3 yes southeast 4.664182  
## 267 40 male 19.800 1 yes southeast 4.235011  
## 268 59 female 32.395 3 no northeast 4.164074  
## 269 45 male 30.200 1 no southwest 3.871634  
## 270 49 male 25.840 1 no northeast 3.967664  
## 271 18 male 29.370 1 no southeast 3.235386  
## 272 50 male 34.200 2 yes southwest 4.632020  
## 273 41 male 37.050 2 no northwest 3.861278  
## 274 50 male 27.455 1 no northeast 3.983070  
## 275 25 male 27.550 0 no northwest 3.401946  
## 276 47 female 26.600 2 no northeast 3.987480  
## 277 19 male 20.615 2 no northwest 3.447731  
## 278 22 female 24.300 0 no southwest 3.332533  
## 279 59 male 31.790 2 no southeast 4.111558  
## 280 51 female 21.560 1 no southeast 3.993662  
## 281 40 female 28.120 1 yes northeast 4.348919  
## 282 54 male 40.565 3 yes northeast 4.686182  
## 283 30 male 27.645 1 no northeast 3.627071  
## 284 55 female 32.395 1 no northeast 4.074784  
## 285 52 female 31.200 0 no southwest 3.983442  
## 286 46 male 26.620 1 no southeast 3.888859  
## 287 46 female 48.070 2 no northeast 3.974646  
## 288 63 female 26.220 0 no northwest 4.154004  
## 289 59 female 36.765 1 yes northeast 4.680306  
## 290 52 male 26.400 3 no southeast 4.414853  
## 291 28 female 33.400 0 no southwest 3.501336  
## 292 29 male 29.640 1 no northeast 4.307021  
## 293 25 male 45.540 2 yes southeast 4.624408  
## 294 22 female 28.820 0 no southeast 3.333800  
## 295 25 male 26.800 3 no southwest 3.591746  
## 296 18 male 22.990 0 no northeast 3.231614  
## 297 19 male 27.700 0 yes southwest 4.212130  
## 298 47 male 25.410 1 yes southeast 4.342002  
## 299 31 male 34.390 3 yes northwest 4.588231  
## 300 48 female 28.880 1 no northwest 3.966118  
## 301 36 male 27.550 3 no northeast 3.829094  
## 302 53 female 22.610 3 yes northeast 4.395735  
## 303 56 female 37.510 2 no southeast 4.088686  
## 304 28 female 33.000 2 no southeast 3.638436  
## 305 57 female 38.000 2 no southwest 4.101960  
## 306 29 male 33.345 2 no northwest 4.288749  
## 307 28 female 27.500 2 no southwest 4.304871  
## 308 30 female 33.330 1 no southeast 3.618156  
## 309 58 male 34.865 0 no northeast 4.077171  
## 310 41 female 33.060 2 no northwest 3.889254  
## 311 50 male 26.600 0 no southwest 3.926573  
## 312 19 female 24.700 0 no southwest 3.239894  
## 313 43 male 35.970 3 yes southeast 4.624535  
## 314 49 male 35.860 0 no southeast 3.909792  
## 315 27 female 31.400 0 yes southwest 4.542064  
## 316 52 male 33.250 0 no northeast 3.987790  
## 317 50 male 32.205 0 no northwest 3.946220  
## 318 54 male 32.775 0 no northeast 4.018495  
## 319 44 female 27.645 0 no northwest 3.870474  
## 320 32 male 37.335 1 no northeast 3.669094  
## 321 34 male 25.270 1 no northwest 3.689731  
## 322 26 female 29.640 4 no northeast 4.392198  
## 323 34 male 30.800 0 yes southwest 4.550126  
## 324 57 male 40.945 0 no northeast 4.063194  
## 325 29 male 27.200 0 no southwest 3.457290  
## 326 40 male 34.105 1 no northeast 3.819557  
## 327 27 female 23.210 1 no southeast 3.551680  
## 328 45 male 36.480 2 yes northwest 4.631043  
## 329 64 female 33.800 1 yes southwest 4.680590  
## 330 52 male 36.700 0 no southwest 3.961163  
## 331 61 female 36.385 1 yes northeast 4.685899  
## 332 52 male 27.360 0 yes northwest 4.387276  
## 333 61 female 31.160 0 no northwest 4.128045  
## 334 56 female 28.785 0 no northeast 4.066638  
## 335 43 female 35.720 2 no northeast 4.282046  
## 336 64 male 34.500 0 no southwest 4.140596  
## 337 60 male 25.740 0 no southeast 4.084311  
## 338 62 male 27.550 1 no northwest 4.144190  
## 339 50 male 32.300 1 yes northeast 4.622412  
## 340 46 female 27.720 1 no southeast 3.915539  
## 341 24 female 27.600 0 no southwest 4.277729  
## 342 62 male 30.020 0 no northwest 4.125550  
## 343 60 female 27.550 0 no northeast 4.121136  
## 344 63 male 36.765 0 no northeast 4.145565  
## 345 49 female 41.470 4 no southeast 4.040492  
## 346 34 female 29.260 3 no southeast 3.791291  
## 347 33 male 35.750 2 no southeast 3.689309  
## 348 46 male 33.345 1 no northeast 3.920877  
## 349 36 female 29.920 1 no southeast 3.738625  
## 350 19 male 27.835 0 no northwest 3.213713  
## 351 57 female 23.180 0 no northwest 4.073007  
## 352 50 female 25.600 0 no southwest 3.950953  
## 353 30 female 27.700 0 no southwest 3.550742  
## 354 33 male 35.245 0 no northeast 4.093593  
## 355 18 female 38.280 0 no southeast 4.150236  
## 356 46 male 27.600 0 no southwest 4.390989  
## 357 46 male 43.890 3 no southeast 3.951537  
## 358 47 male 29.830 3 no northwest 3.983190  
## 359 23 male 41.910 0 no southeast 3.264176  
## 360 18 female 20.790 0 no southeast 3.206154  
## 361 48 female 32.300 2 no northeast 4.001874  
## 362 35 male 30.500 1 no southwest 3.676791  
## 363 19 female 21.700 0 yes southwest 4.141277  
## 364 21 female 26.400 1 no southwest 3.414602  
## 365 21 female 21.890 2 no southeast 3.502497  
## 366 49 female 30.780 1 no northeast 3.990265  
## 367 56 female 32.300 3 no northeast 4.128085  
## 368 42 female 24.985 2 no northwest 3.904015  
## 369 44 male 32.015 2 no northwest 3.909356  
## 370 18 male 30.400 3 no northeast 3.541812  
## 371 61 female 21.090 0 no northwest 4.127592  
## 372 57 female 22.230 0 no northeast 4.080240  
## 373 42 female 33.155 1 no northeast 3.883060  
## 374 26 male 32.900 2 yes southwest 4.557329  
## 375 20 male 33.330 0 no southeast 3.143492  
## 376 23 female 28.310 0 yes northwest 4.256091  
## 377 39 female 24.890 3 yes northeast 4.335657  
## 378 24 male 40.150 0 yes southeast 4.581224  
## 379 64 female 30.115 3 no northwest 4.216317  
## 380 62 male 31.460 1 no southeast 4.431380  
## 381 27 female 17.955 2 yes northeast 4.176282  
## 382 55 male 30.685 0 yes northeast 4.626378  
## 383 55 male 33.000 0 no southeast 4.317677  
## 384 35 female 43.340 2 no southeast 3.766927  
## 385 44 male 22.135 2 no northeast 3.919211  
## 386 19 male 34.400 0 no southwest 3.101011  
## 387 58 female 39.050 0 no southeast 4.073953  
## 388 50 male 25.365 2 no northwest 4.481222  
## 389 26 female 22.610 0 no northwest 3.501992  
## 390 24 female 30.210 3 no northwest 3.664461  
## 391 48 male 35.625 4 no northeast 4.030878  
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## 394 49 male 31.350 1 no northeast 3.968022  
## 395 46 female 32.300 2 no northeast 3.973636  
## 396 46 male 19.855 0 no northwest 3.876605  
## 397 43 female 34.400 3 no southwest 3.930542  
## 398 21 male 31.020 0 no southeast 4.219755  
## 399 64 male 25.600 2 no southwest 4.175756  
## 400 18 female 38.170 0 no southeast 3.212632  
## 401 51 female 20.600 0 no southwest 3.966836  
## 402 47 male 47.520 1 no southeast 3.907622  
## 403 64 female 32.965 0 no northwest 4.167101  
## 404 49 male 32.300 3 no northwest 4.011548  
## 405 31 male 20.400 0 no southwest 3.513244  
## 406 52 female 38.380 2 no northeast 4.056787  
## 407 33 female 24.310 0 no southeast 3.621706  
## 408 47 female 23.600 1 no southwest 3.931441  
## 409 38 male 21.120 3 no southeast 3.822987  
## 410 32 male 30.030 1 no southeast 3.610069  
## 411 19 male 17.480 0 no northwest 3.209874  
## 412 44 female 20.235 1 yes northeast 4.292141  
## 413 26 female 17.195 2 yes northeast 4.160037  
## 414 25 male 23.900 5 no southwest 3.705872  
## 415 19 female 35.150 0 no northwest 3.329378  
## 416 43 female 35.640 1 no southeast 3.866035  
## 417 52 male 34.100 0 no southeast 3.960991  
## 418 36 female 22.600 2 yes southwest 4.269706  
## 419 64 male 39.160 1 no southeast 4.158913  
## 420 63 female 26.980 0 yes northwest 4.461656  
## 421 64 male 33.880 0 yes southeast 4.671073  
## 422 61 male 35.860 0 yes southeast 4.668378  
## 423 40 male 32.775 1 yes northeast 4.592458  
## 424 25 male 30.590 0 no northeast 3.435748  
## 425 48 male 30.200 2 no southwest 3.952712  
## 426 45 male 24.310 5 no southeast 3.990732  
## 427 38 female 27.265 1 no northeast 3.816577  
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## 429 21 female 16.815 1 no northeast 3.500711  
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## 433 42 male 26.900 0 no southwest 3.775954  
## 434 60 female 30.500 0 no southwest 4.101685  
## 435 31 male 28.595 1 no northwest 3.627733  
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## 437 22 male 31.730 0 no northeast 3.353107  
## 438 35 male 28.900 3 no southwest 3.772824  
## 439 52 female 46.750 5 no southeast 4.100113  
## 440 26 male 29.450 0 no northeast 3.461997  
## 441 31 female 32.680 1 no northwest 3.675620  
## 442 33 female 33.500 0 yes southwest 4.569132  
## 443 18 male 43.010 0 no southeast 3.060470  
## 444 59 female 36.520 1 no southeast 4.451601  
## 445 56 male 26.695 1 yes northwest 4.416796  
## 446 45 female 33.100 0 no southwest 3.865997  
## 447 60 male 29.640 0 no northeast 4.104863  
## 448 56 female 25.650 0 no northwest 4.058958  
## 449 40 female 29.600 0 no southwest 3.771657  
## 450 35 male 38.600 1 no southwest 3.677819  
## 451 39 male 29.600 4 no southwest 3.875771  
## 452 30 male 24.130 1 no northwest 3.605546  
## 453 24 male 23.400 0 no southwest 3.294381  
## 454 20 male 29.735 0 no northwest 3.247858  
## 455 32 male 46.530 2 no southeast 3.670838  
## 456 59 male 37.400 0 no southwest 4.338397  
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## 461 49 female 36.630 3 no southeast 4.016259  
## 462 42 male 30.000 0 yes southwest 4.345257  
## 463 62 female 38.095 2 no northeast 4.182709  
## 464 56 male 25.935 0 no northeast 4.047875  
## 465 19 male 25.175 0 no northwest 3.212730  
## 466 30 female 28.380 1 yes southeast 4.290524  
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## 468 56 female 33.820 2 no northwest 4.101863  
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## 470 18 female 24.090 1 no southeast 3.342639  
## 471 27 male 32.670 0 no southeast 3.397425  
## 472 18 female 30.115 0 no northeast 3.343108  
## 473 19 female 29.800 0 no southwest 3.241662  
## 474 47 female 33.345 0 no northeast 4.319705  
## 475 54 male 25.100 3 yes southwest 4.404531  
## 476 61 male 28.310 1 yes northwest 4.460427  
## 477 24 male 28.500 0 yes northeast 4.545895  
## 478 25 male 35.625 0 no northwest 3.403874  
## 479 21 male 36.850 0 no southeast 3.185912  
## 480 23 male 32.560 0 no southeast 3.261093  
## 481 63 male 41.325 3 no northwest 4.191875  
## 482 49 male 37.510 2 no southeast 3.968702  
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## 485 48 male 34.300 3 no southwest 3.980595  
## 486 31 female 31.065 0 no northeast 3.638192  
## 487 54 female 21.470 3 no northwest 4.096053  
## 488 19 male 28.700 0 no southwest 3.098275  
## 489 44 female 38.060 0 yes southeast 4.689177  
## 490 53 male 31.160 1 no northwest 4.019614  
## 491 19 female 32.900 0 no southwest 3.242734  
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## 493 18 female 25.080 0 no northeast 3.341726  
## 494 61 male 43.400 0 no southwest 4.099475  
## 495 21 male 25.700 4 yes southwest 4.253873  
## 496 20 male 27.930 0 no northeast 3.293809  
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## 498 45 male 28.700 2 no southwest 3.904606  
## 499 44 female 23.980 2 no southeast 3.914401  
## 500 62 female 39.200 0 no southwest 4.129395  
## 501 29 male 34.400 0 yes southwest 4.558681  
## 502 43 male 26.030 0 no northeast 3.834889  
## 503 51 male 23.210 1 yes southeast 4.346707  
## 504 19 male 30.250 0 yes southeast 4.512529  
## 505 38 female 28.930 1 no southeast 3.776293  
## 506 37 male 30.875 3 no northwest 3.832309  
## 507 22 male 31.350 1 no northwest 3.422141  
## 508 21 male 23.750 2 no northwest 3.488141  
## 509 24 female 25.270 0 no northeast 3.483475  
## 510 57 female 28.700 0 no southwest 4.059006  
## 511 56 male 32.110 1 no northeast 4.070518  
## 512 27 male 33.660 0 no southeast 3.397664  
## 513 51 male 22.420 0 no northeast 3.971337  
## 514 19 male 30.400 0 no southwest 3.099093  
## 515 39 male 28.300 1 yes southwest 4.323915  
## 516 58 male 35.700 0 no southwest 4.055484  
## 517 20 male 35.310 1 no southeast 4.442860  
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## 519 35 female 31.000 1 no southwest 3.719395  
## 520 31 male 30.875 0 no northeast 3.586335  
## 521 50 female 27.360 0 no northeast 4.409199  
## 522 32 female 44.220 0 no southeast 3.601427  
## 523 51 female 33.915 0 no northeast 3.994155  
## 524 38 female 37.730 0 no southeast 3.732202  
## 525 42 male 26.070 1 yes southeast 4.582581  
## 526 18 female 33.880 0 no southeast 4.060042  
## 527 19 female 30.590 2 no northwest 4.381290  
## 528 51 female 25.800 1 no southwest 3.993922  
## 529 46 male 39.425 1 no northeast 3.921317  
## 530 18 male 25.460 0 no northeast 3.232488  
## 531 57 male 42.130 1 yes southeast 4.687311  
## 532 62 female 31.730 0 no northeast 4.147475  
## 533 59 male 29.700 2 no southeast 4.111460  
## 534 37 male 36.190 0 no southeast 4.283634  
## 535 64 male 40.480 0 no southeast 4.140857  
## 536 38 male 28.025 1 no northeast 3.782983  
## 537 33 female 38.900 3 no southwest 3.776147  
## 538 46 female 30.200 2 no southwest 3.945719  
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## 540 53 male 31.350 0 no southeast 4.436894  
## 541 34 female 38.000 3 no southwest 3.792143  
## 542 20 female 31.790 2 no southeast 3.485209  
## 543 63 female 36.300 0 no southeast 4.142615  
## 544 54 female 47.410 0 yes southeast 4.804619  
## 545 54 male 30.210 0 no northwest 4.009939  
## 546 49 male 25.840 2 yes northwest 4.376709  
## 547 28 male 35.435 0 no northeast 3.514395  
## 548 54 female 46.700 2 no southwest 4.062146  
## 549 25 female 28.595 0 no northeast 3.506995  
## 550 43 female 46.200 0 yes southeast 4.661464  
## 551 63 male 30.800 0 no southwest 4.126799  
## 552 32 female 28.930 0 no southeast 3.599110  
## 553 62 male 21.400 0 no southwest 4.112508  
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## 588 34 female 30.210 1 yes northwest 4.642898  
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## 597 42 female 29.480 2 no southeast 3.883111  
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## 599 43 male 32.600 2 no southwest 3.871661  
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## 604 64 female 39.050 3 no southeast 4.206425  
## 605 19 female 28.310 0 yes northwest 4.242268  
## 606 51 female 34.100 0 no southeast 3.967715  
## 607 27 female 25.175 0 no northeast 3.551282  
## 608 59 female 23.655 0 yes northwest 4.409574  
## 609 28 male 26.980 2 no northeast 3.646903  
## 610 30 male 37.800 2 yes southwest 4.593745  
## 611 47 female 29.370 1 no southeast 3.931849  
## 612 38 female 34.800 2 no southwest 3.817667  
## 613 18 female 33.155 0 no northeast 3.343940  
## 614 34 female 19.000 3 no northeast 3.829499  
## 615 20 female 33.000 0 no southeast 3.274174  
## 616 47 female 36.630 1 yes southeast 4.633164  
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## 635 51 male 39.700 1 no southwest 3.972728  
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## 817 24 female 24.225 0 no northwest 3.453740  
## 818 23 male 37.100 3 no southwest 3.556012  
## 819 47 female 26.125 1 yes northeast 4.369240  
## 820 33 female 35.530 0 yes northwest 4.741431  
## 821 45 male 33.700 1 no southwest 3.871918  
## 822 26 male 17.670 0 no northwest 3.428289  
## 823 18 female 31.130 0 no southeast 3.210019  
## 824 44 female 29.810 2 no southeast 3.914830  
## 825 60 male 24.320 0 no northwest 4.097729  
## 826 64 female 31.825 2 no northeast 4.205991  
## 827 56 male 31.790 2 yes southeast 4.641612  
## 828 36 male 28.025 1 yes northeast 4.317512  
## 829 41 male 30.780 3 yes northeast 4.597667  
## 830 39 male 21.850 1 no northwest 3.786574  
## 831 63 male 33.100 0 no southwest 4.126902  
## 832 36 female 25.840 0 no northwest 3.721511  
## 833 28 female 23.845 2 no northwest 3.673918  
## 834 58 male 34.390 0 no northwest 4.069814  
## 835 36 male 33.820 1 no northwest 3.730577  
## 836 42 male 35.970 2 no southeast 3.854933  
## 837 36 male 31.500 0 no southwest 3.643673  
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## 839 35 female 23.465 2 no northeast 3.806335  
## 840 59 female 31.350 0 no northwest 4.101134  
## 841 21 male 31.100 0 no southwest 3.183643  
## 842 59 male 24.700 0 no northeast 4.090749  
## 843 23 female 32.780 2 yes southeast 4.556556  
## 844 57 female 29.810 0 yes southeast 4.439868  
## 845 53 male 30.495 0 no northeast 4.003118  
## 846 60 female 32.450 0 yes southeast 4.653299  
## 847 51 female 34.200 1 no southwest 3.994436  
## 848 23 male 50.380 1 no southeast 3.387044  
## 849 27 female 24.100 0 no southwest 3.473359  
## 850 55 male 32.775 0 no northwest 4.025373  
## 851 37 female 30.780 0 yes northeast 4.571361  
## 852 61 male 32.300 2 no northwest 4.149823  
## 853 46 female 35.530 0 yes northeast 4.624402  
## 854 53 female 23.750 2 no northeast 4.069286  
## 855 49 female 23.845 3 yes northeast 4.382142  
## 856 20 female 29.600 0 no southwest 3.273081  
## 857 48 female 33.110 0 yes southeast 4.612510  
## 858 25 male 24.130 0 yes northwest 4.199151  
## 859 25 female 32.230 1 no southeast 4.260505  
## 860 57 male 28.100 0 no southwest 4.040026  
## 861 37 female 47.600 2 yes southwest 4.663828  
## 862 38 female 28.000 3 no southwest 3.854372  
## 863 55 female 33.535 2 no northwest 4.088834  
## 864 36 female 19.855 0 no northeast 3.737037  
## 865 51 male 25.400 0 no southwest 3.943617  
## 866 40 male 29.900 2 no southwest 3.819568  
## 867 18 male 37.290 0 no southeast 3.057455  
## 868 57 male 43.700 1 no southwest 4.063563  
## 869 61 male 23.655 0 no northeast 4.118252  
## 870 25 female 24.300 3 no southwest 3.642628  
## 871 50 male 36.200 0 no southwest 3.927258  
## 872 26 female 29.480 1 no southeast 3.530503  
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## 887 57 male 28.975 0 yes northeast 4.434863  
## 888 36 female 30.020 0 no northwest 3.721990  
## 889 22 male 39.500 0 no southwest 3.225980  
## 890 57 male 33.630 1 no northwest 4.077191  
## 891 64 female 26.885 0 yes northwest 4.467327  
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## 893 54 male 24.035 0 no northeast 4.017989  
## 894 47 male 38.940 2 yes southeast 4.645448  
## 895 62 male 32.110 0 no northeast 4.132100  
## 896 61 female 44.000 0 no southwest 4.116072  
## 897 43 female 20.045 2 yes northeast 4.296623  
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## 908 44 female 32.340 1 no southeast 3.882736  
## 909 63 male 39.800 3 no southwest 4.180988  
## 910 32 female 24.600 0 yes southwest 4.242946  
## 911 22 male 28.310 1 no northwest 3.421446  
## 912 18 male 31.730 0 yes northeast 4.528051  
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## 917 43 female 26.885 0 yes northwest 4.337945  
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## 920 35 female 34.210 1 no southeast 3.719764  
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## 925 43 male 23.200 0 no southwest 3.795910  
## 926 50 male 32.110 2 no northeast 4.403692  
## 927 19 female 23.400 2 no southwest 3.464425  
## 928 57 female 20.100 1 no southwest 4.080350  
## 929 62 female 39.160 0 no southeast 4.129394  
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## 934 45 female 35.300 0 no southwest 3.866178  
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## 937 44 male 29.735 2 no northeast 4.506622  
## 938 39 female 24.225 5 no northwest 3.952589  
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## 945 62 male 39.930 0 no southeast 4.113371  
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## 952 51 male 42.900 2 yes southeast 4.676354  
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## 955 34 male 27.835 1 yes northwest 4.301239  
## 956 31 male 39.490 1 no southeast 3.588354  
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## 958 24 male 26.790 1 no northwest 4.100711  
## 959 43 male 34.960 1 yes northeast 4.613146  
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## 1008 47 male 28.215 3 yes northwest 4.396465  
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## 1036 54 female 23.000 3 no southwest 4.082587  
## 1037 22 male 37.070 2 yes southeast 4.573851  
## 1038 45 female 30.495 1 yes northwest 4.599070  
## 1039 22 male 28.880 0 no northeast 3.352344  
## 1040 19 male 27.265 2 no northwest 4.352060  
## 1041 35 female 28.025 0 yes northwest 4.306100  
## 1042 18 male 23.085 0 no northeast 3.231648  
## 1043 20 male 30.685 0 yes northeast 4.524731  
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## 1047 43 female 25.080 0 no northeast 3.864810  
## 1048 22 male 52.580 1 yes southeast 4.648374  
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## 1107 49 female 29.925 0 no northwest 3.953671  
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## 1118 25 male 33.330 2 yes southeast 4.557803  
## 1119 33 male 35.750 1 yes southeast 4.583003  
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## 1123 53 female 36.860 3 yes northwest 4.668958  
## 1124 27 female 32.395 1 no northeast 4.276542  
## 1125 23 female 42.750 1 yes northeast 4.611768  
## 1126 63 female 25.080 0 no northwest 4.153955  
## 1127 55 male 29.900 0 no southwest 4.009223  
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## 1130 19 female 18.600 0 no southwest 3.237769  
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## 1132 27 male 45.900 2 no southwest 3.567430  
## 1133 57 male 40.280 0 no northeast 4.316160  
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## 1135 28 male 33.820 0 no northwest 4.293878  
## 1136 50 female 28.120 3 no northwest 4.044759  
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## 1165 41 female 28.310 1 no northwest 3.854522  
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## 1188 62 female 32.680 0 no northwest 4.141287  
## 1189 43 female 25.270 1 yes northeast 4.337885  
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## 1225 41 male 23.940 1 no northeast 3.836228  
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## 1248 33 male 29.400 4 no southwest 3.782413  
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## 1250 32 male 33.630 1 yes northeast 4.575275  
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## 1253 20 male 27.300 0 yes southwest 4.210395  
## 1254 40 female 29.300 4 no southwest 4.199449  
## 1255 34 female 27.720 0 no southeast 3.644946  
## 1256 42 female 37.900 0 no southwest 3.811174  
## 1257 51 female 36.385 3 no northwest 4.058302  
## 1258 54 female 27.645 1 no northwest 4.053306  
## 1259 55 male 37.715 3 no northwest 4.478041  
## 1260 52 female 23.180 0 no northeast 4.008505  
## 1261 32 female 20.520 0 no northeast 3.657461  
## 1262 28 male 37.100 1 no southwest 3.515498  
## 1263 41 female 28.050 1 no southeast 3.830601  
## 1264 43 female 29.900 1 no southwest 3.865563  
## 1265 49 female 33.345 2 no northeast 4.015817  
## 1266 64 male 23.760 0 yes southeast 4.430180  
## 1267 55 female 30.500 0 no southwest 4.029565  
## 1268 24 male 31.065 0 yes northeast 4.534712  
## 1269 20 female 33.300 0 no southwest 3.274270  
## 1270 45 male 27.500 3 no southwest 3.935270  
## 1271 26 male 33.915 1 no northwest 3.517530  
## 1272 25 female 34.485 0 no northwest 3.480267  
## 1273 43 male 25.520 5 no southeast 4.160718  
## 1274 35 male 27.610 1 no southeast 3.676424  
## 1275 26 male 27.060 0 yes southeast 4.231555  
## 1276 57 male 23.700 0 no southwest 4.039784  
## 1277 22 female 30.400 0 no northeast 3.438059  
## 1278 32 female 29.735 0 no northwest 3.639192  
## 1279 39 male 29.925 1 yes northeast 4.351449  
## 1280 25 female 26.790 2 no northwest 3.622122  
## 1281 48 female 33.330 0 no southeast 3.918223  
## 1282 47 female 27.645 2 yes northwest 4.389798  
## 1283 18 female 21.660 0 yes northeast 4.154833  
## 1284 18 male 30.030 1 no southeast 3.235618  
## 1285 61 male 36.300 1 yes southwest 4.675814  
## 1286 47 female 24.320 0 no northeast 3.931187  
## 1287 28 female 17.290 0 no northeast 3.572014  
## 1288 36 female 25.900 1 no southwest 3.738182  
## 1289 20 male 39.400 2 yes southwest 4.583704  
## 1290 44 male 34.320 1 no southeast 3.854153  
## 1291 38 female 19.950 2 no northeast 3.853327  
## 1292 19 male 34.900 0 yes southwest 4.541937  
## 1293 21 male 23.210 0 no southeast 3.180511  
## 1294 46 male 25.745 3 no northwest 3.968571  
## 1295 58 male 25.175 0 no northeast 4.076681  
## 1296 20 male 22.000 1 no southwest 3.293314  
## 1297 18 male 26.125 0 no northeast 3.232723  
## 1298 28 female 26.510 2 no southeast 3.637534  
## 1299 33 male 27.455 2 no northwest 3.721107  
## 1300 19 female 25.745 1 no northwest 3.433102  
## 1301 45 male 30.360 0 yes southeast 4.796525  
## 1302 62 male 30.875 3 yes northwest 4.669486  
## 1303 25 female 20.800 1 no southwest 3.506341  
## 1304 43 male 27.800 0 yes southwest 4.577833  
## 1305 42 male 24.605 2 yes northeast 4.327551  
## 1306 24 female 27.720 0 no southeast 3.391750  
## 1307 29 female 21.850 0 yes northeast 4.207239  
## 1308 32 male 28.120 4 yes northwest 4.331882  
## 1309 25 female 30.200 0 yes southwest 4.530208  
## 1310 41 male 32.200 2 no southwest 3.837333  
## 1311 42 male 26.315 1 no northwest 3.841416  
## 1312 33 female 26.695 0 no northwest 3.660050  
## 1313 34 male 42.900 1 no southwest 3.656698  
## 1314 19 female 34.700 2 yes southwest 4.561072  
## 1315 30 female 23.655 3 yes northwest 4.273369  
## 1316 18 male 28.310 1 no northeast 4.052014  
## 1317 19 female 20.600 0 no southwest 3.238467  
## 1318 18 male 53.130 0 no southeast 3.065752  
## 1319 35 male 39.710 4 no northeast 4.289962  
## 1320 39 female 26.315 2 no northwest 3.857435  
## 1321 31 male 31.065 3 no northwest 3.734402  
## 1322 62 male 26.695 0 yes northeast 4.448727  
## 1323 62 male 38.830 0 no southeast 4.113320  
## 1324 42 female 40.370 2 yes southeast 4.642429  
## 1325 31 male 25.935 1 no northwest 3.627355  
## 1326 61 male 33.535 0 no northeast 4.118706  
## 1327 42 female 32.870 0 no northeast 3.848190  
## 1328 51 male 30.030 1 no southeast 3.972106  
## 1329 23 female 24.225 2 no northeast 4.350165  
## 1330 52 male 38.600 2 no southwest 4.013899  
## 1331 57 female 25.740 2 no southeast 4.101375  
## 1332 23 female 33.400 0 no southwest 4.033260  
## 1333 52 female 44.700 3 no southwest 4.057350  
## 1334 50 male 30.970 3 no northwest 4.025328  
## 1335 18 female 31.920 0 no northeast 3.343602  
## 1336 18 female 36.850 0 no southeast 3.212143  
## 1337 21 female 25.800 0 no southwest 3.302752  
## 1338 61 female 29.070 0 yes northwest 4.464510

# Split the data into training and test sets  
set.seed(122) # Set the seed to make the partition reproducible  
training.samples <- df$logCharges %>%  
 createDataPartition(p = 0.8, list = FALSE)  
train <- df[training.samples, ]  
test <- df[-training.samples, ]

## Multi Linear Regression

# Fitting Multiple Linear Regression to the Training set  
regressor = lm(formula = logCharges ~ ., data = train)  
  
# Predicting the Test set results  
y\_pred = predict(regressor, newdata = test)

# Building the optimal model using Backward Elimination  
regressor = lm(formula = logCharges ~ smoker + bmi + age + children,  
 data = train)  
summary(regressor)

##   
## Call:  
## lm(formula = logCharges ~ smoker + bmi + age + children, data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.43267 -0.09410 -0.02047 0.03472 0.90336   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.0091840 0.0327880 91.777 < 0.0000000000000002 \*\*\*  
## smokeryes 0.6717664 0.0144861 46.373 < 0.0000000000000002 \*\*\*  
## bmi 0.0048142 0.0009560 5.036 0.0000005589842985 \*\*\*  
## age 0.0153830 0.0004178 36.817 < 0.0000000000000002 \*\*\*  
## children1 0.0526695 0.0148089 3.557 0.000392 \*\*\*  
## children2 0.1273607 0.0162623 7.832 0.0000000000000116 \*\*\*  
## children3 0.1096260 0.0190973 5.740 0.0000000123148700 \*\*\*  
## children4 0.2065459 0.0415253 4.974 0.0000007644571002 \*\*\*  
## children5 0.1708113 0.0556906 3.067 0.002216 \*\*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.1902 on 1063 degrees of freedom  
## Multiple R-squared: 0.774, Adjusted R-squared: 0.7723   
## F-statistic: 455 on 8 and 1063 DF, p-value: < 0.00000000000000022

regressor = lm(formula = logCharges ~ smoker + bmi + age,  
 data = train)  
summary(regressor)

##   
## Call:  
## lm(formula = logCharges ~ smoker + bmi + age, data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.48832 -0.09521 -0.01820 0.04612 0.90245   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.0483716 0.0336971 90.464 < 0.0000000000000002 \*\*\*  
## smokeryes 0.6717732 0.0150443 44.653 < 0.0000000000000002 \*\*\*  
## bmi 0.0051270 0.0009949 5.153 0.000000305 \*\*\*  
## age 0.0155505 0.0004338 35.847 < 0.0000000000000002 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.198 on 1068 degrees of freedom  
## Multiple R-squared: 0.7538, Adjusted R-squared: 0.7531   
## F-statistic: 1090 on 3 and 1068 DF, p-value: < 0.00000000000000022

regressor = lm(formula = logCharges ~ smoker + bmi,  
 data = train)  
summary(regressor)

##   
## Call:  
## lm(formula = logCharges ~ smoker + bmi, data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.86945 -0.18151 0.03882 0.19310 0.76208   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 3.542673 0.045616 77.662 < 0.0000000000000002 \*\*\*  
## smokeryes 0.651047 0.022304 29.190 < 0.0000000000000002 \*\*\*  
## bmi 0.009004 0.001467 6.136 0.00000000119 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.2938 on 1069 degrees of freedom  
## Multiple R-squared: 0.4575, Adjusted R-squared: 0.4565   
## F-statistic: 450.7 on 2 and 1069 DF, p-value: < 0.00000000000000022

library(ridge)   
# Linear Ridge  
  
linRidgeMod = linearRidge(logCharges ~ ., data = train)  
predicted = predict(linRidgeMod, test) # predict on test data  
compare1 = cbind (actual=test$logCharges, predicted)  
  
summary(linRidgeMod)

##   
## Call:  
## linearRidge(formula = logCharges ~ ., data = train)  
##   
##   
## Coefficients:  
## Estimate Scaled estimate Std. Error (scaled)  
## (Intercept) 3.30297677 NA NA  
## age 0.00929640 4.27152666 0.15559432  
## sexmale -0.02915808 -0.47730851 0.13198861  
## bmi -0.00145019 -0.29048685 0.14480523  
## children1 0.05049776 0.70773365 0.14311672  
## children2 0.08768795 1.10974346 0.14271249  
## children3 0.08344239 0.88589104 0.14001409  
## children4 0.15305531 0.71048842 0.13317015  
## children5 0.15881510 0.54706375 0.13250258  
## smokeryes 0.14952019 1.97042375 0.24340272  
## regionnorthwest -0.01979536 -0.28064772 0.16164160  
## regionsoutheast -0.04597714 -0.66128119 0.16792405  
## regionsouthwest -0.04039165 -0.56977292 0.16204902  
## charges 0.00002236 8.80624906 0.26059639  
## t value (scaled) Pr(>|t|)   
## (Intercept) NA NA   
## age 27.453 < 0.0000000000000002 \*\*\*  
## sexmale 3.616 0.000299 \*\*\*  
## bmi 2.006 0.044851 \*   
## children1 4.945 0.000000760853017479 \*\*\*  
## children2 7.776 0.000000000000007550 \*\*\*  
## children3 6.327 0.000000000249720467 \*\*\*  
## children4 5.335 0.000000095443154713 \*\*\*  
## children5 4.129 0.000036481571797919 \*\*\*  
## smokeryes 8.095 0.000000000000000666 \*\*\*  
## regionnorthwest 1.736 0.082522 .   
## regionsoutheast 3.938 0.000082171165242118 \*\*\*  
## regionsouthwest 3.516 0.000438 \*\*\*  
## charges 33.793 < 0.0000000000000002 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Ridge parameter: 0.002308026, chosen automatically, computed using 10 PCs  
##   
## Degrees of freedom: model 12.95 , variance 12.9 , residual 13

mean (apply(compare1, 1, min)/apply(compare1, 1, max))

## [1] 0.9769878

RMSE = sqrt(mean((test$logCharges-predicted)^2))  
RMSE

## [1] 0.1335739

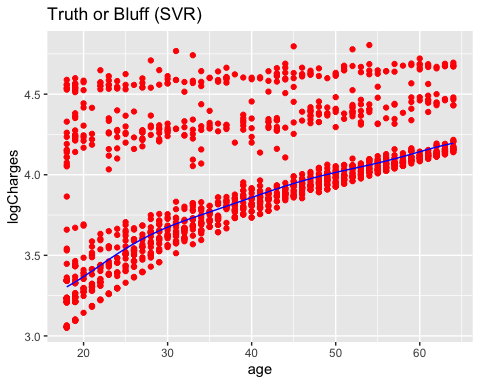
## SVR

library(e1071)

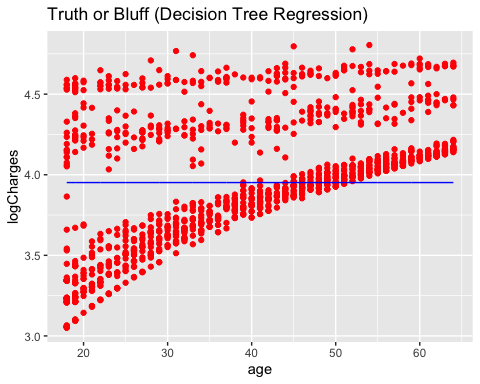
##   
## Attaching package: 'e1071'

## The following object is masked from 'package:Hmisc':  
##   
## impute

regressor = svm(formula = logCharges ~ age,  
 data = df,  
 type = 'eps-regression',  
 kernel = 'radial')  
  
# Predicting a new result  
y\_pred = predict(regressor, data.frame(age = 37))  
  
# Visualising the SVR results  
# install.packages('ggplot2')  
library(ggplot2)  
ggplot() +  
 geom\_point(aes(x = df$age, y = df$logCharges),  
 colour = 'red') +  
 geom\_line(aes(x = df$age, y = predict(regressor, newdata = df)),  
 colour = 'blue') +  
 ggtitle('Truth or Bluff (SVR)') +  
 xlab('age') +  
 ylab('logCharges')

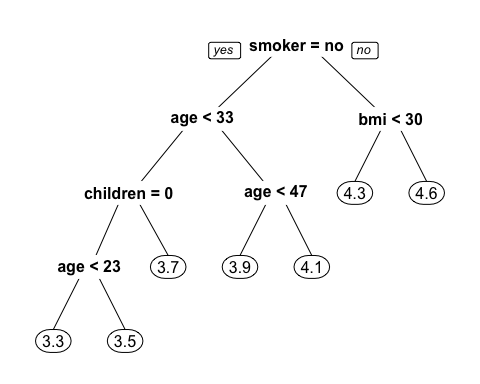


# Fitting Decision Tree Regression to the dataset  
# install.packages('rpart')  
library(rpart)  
regressor = rpart(formula = logCharges ~ age,  
 data = df,  
 control = rpart.control(minsplit = 1))  
  
  
# Predicting a new result  
y\_pred = predict(regressor, data.frame(age = 37))  
  
# Visualising the Decision Tree Regression results (higher resolution)  
# install.packages('ggplot2')  
library(ggplot2)  
ggplot() +  
 geom\_point(aes(x = df$age, y = df$logCharges),  
 colour = 'red') +  
 geom\_line(aes(x = df$age, y = predict(regressor, newdata = df)),  
 colour = 'blue') +  
 ggtitle('Truth or Bluff (Decision Tree Regression)') +  
 xlab('age') +  
 ylab('logCharges')



library(rpart)  
library(rpart.plot)

tree = rpart(logCharges ~ smoker + bmi + age + children + sex + region, data=df)  
prp(tree)



print(tree, digits = 2)

## n= 1338   
##   
## node), split, n, deviance, yval  
## \* denotes terminal node  
##   
## 1) root 1338 210.00 4.0   
## 2) smoker=no 1064 110.00 3.8   
## 4) age< 32 392 35.00 3.5   
## 8) children=0 207 14.00 3.4   
## 16) age< 22 121 6.70 3.3 \*  
## 17) age>=22 86 4.80 3.5 \*  
## 9) children=1,2,3,4,5 185 14.00 3.7 \*  
## 5) age>=32 672 22.00 4.0   
## 10) age< 46 288 6.50 3.9 \*  
## 11) age>=46 384 6.70 4.1 \*  
## 3) smoker=yes 274 7.70 4.5   
## 6) bmi< 30 130 1.20 4.3 \*  
## 7) bmi>=30 144 0.48 4.6 \*

## Random Forest

myControl = trainControl(method = "cv", number = 5, verboseIter = FALSE)  
model\_rf = train(logCharges ~ smoker + bmi + age + children + sex + region, data = train,  
 tuneLength = 1,  
 method = "ranger",  
 importance = 'impurity',  
 trControl = myControl)  
model\_rf

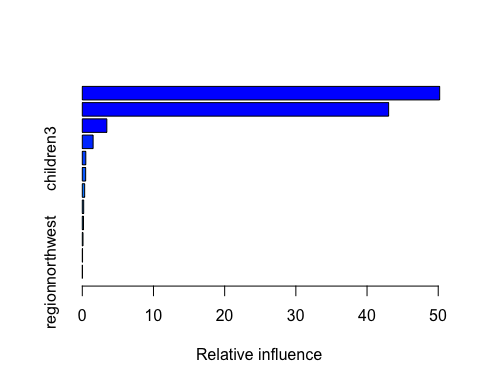
## Random Forest   
##   
## 1072 samples  
## 6 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (5 fold)   
## Summary of sample sizes: 856, 857, 858, 858, 859   
## Resampling results across tuning parameters:  
##   
## splitrule RMSE Rsquared MAE   
## variance 0.1727875 0.8297888 0.1130003  
## extratrees 0.1796149 0.8260375 0.1245521  
##   
## Tuning parameter 'mtry' was held constant at a value of 3  
## Tuning  
## parameter 'min.node.size' was held constant at a value of 5  
## RMSE was used to select the optimal model using the smallest value.  
## The final values used for the model were mtry = 3, splitrule = variance  
## and min.node.size = 5.

## gbm

model\_gbm = train(logCharges ~ smoker + bmi + age + children + sex + region,   
 data = train,  
 tuneLength = 2,  
 method = "gbm",  
 trControl = myControl)

## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1440 nan 0.1000 0.0139  
## 2 0.1334 nan 0.1000 0.0118  
## 3 0.1247 nan 0.1000 0.0081  
## 4 0.1176 nan 0.1000 0.0071  
## 5 0.1116 nan 0.1000 0.0056  
## 6 0.1049 nan 0.1000 0.0065  
## 7 0.0994 nan 0.1000 0.0052  
## 8 0.0944 nan 0.1000 0.0043  
## 9 0.0897 nan 0.1000 0.0045  
## 10 0.0860 nan 0.1000 0.0036  
## 20 0.0602 nan 0.1000 0.0016  
## 40 0.0437 nan 0.1000 0.0001  
## 60 0.0394 nan 0.1000 0.0001  
## 80 0.0378 nan 0.1000 -0.0001  
## 100 0.0370 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1364 nan 0.1000 0.0217  
## 2 0.1194 nan 0.1000 0.0187  
## 3 0.1052 nan 0.1000 0.0138  
## 4 0.0936 nan 0.1000 0.0124  
## 5 0.0840 nan 0.1000 0.0089  
## 6 0.0760 nan 0.1000 0.0080  
## 7 0.0688 nan 0.1000 0.0065  
## 8 0.0639 nan 0.1000 0.0056  
## 9 0.0594 nan 0.1000 0.0047  
## 10 0.0564 nan 0.1000 0.0025  
## 20 0.0381 nan 0.1000 0.0010  
## 40 0.0297 nan 0.1000 0.0001  
## 60 0.0276 nan 0.1000 -0.0000  
## 80 0.0264 nan 0.1000 0.0000  
## 100 0.0256 nan 0.1000 -0.0001  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1447 nan 0.1000 0.0128  
## 2 0.1336 nan 0.1000 0.0109  
## 3 0.1252 nan 0.1000 0.0081  
## 4 0.1182 nan 0.1000 0.0068  
## 5 0.1111 nan 0.1000 0.0067  
## 6 0.1047 nan 0.1000 0.0060  
## 7 0.0992 nan 0.1000 0.0058  
## 8 0.0943 nan 0.1000 0.0048  
## 9 0.0897 nan 0.1000 0.0044  
## 10 0.0855 nan 0.1000 0.0041  
## 20 0.0584 nan 0.1000 0.0010  
## 40 0.0419 nan 0.1000 0.0003  
## 60 0.0380 nan 0.1000 0.0001  
## 80 0.0366 nan 0.1000 -0.0000  
## 100 0.0358 nan 0.1000 -0.0002  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1362 nan 0.1000 0.0221  
## 2 0.1192 nan 0.1000 0.0173  
## 3 0.1051 nan 0.1000 0.0143  
## 4 0.0939 nan 0.1000 0.0119  
## 5 0.0842 nan 0.1000 0.0089  
## 6 0.0758 nan 0.1000 0.0083  
## 7 0.0687 nan 0.1000 0.0068  
## 8 0.0631 nan 0.1000 0.0056  
## 9 0.0585 nan 0.1000 0.0045  
## 10 0.0543 nan 0.1000 0.0037  
## 20 0.0378 nan 0.1000 0.0011  
## 40 0.0291 nan 0.1000 0.0001  
## 60 0.0266 nan 0.1000 0.0000  
## 80 0.0249 nan 0.1000 0.0000  
## 100 0.0238 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1438 nan 0.1000 0.0119  
## 2 0.1334 nan 0.1000 0.0108  
## 3 0.1248 nan 0.1000 0.0083  
## 4 0.1183 nan 0.1000 0.0070  
## 5 0.1116 nan 0.1000 0.0068  
## 6 0.1059 nan 0.1000 0.0055  
## 7 0.1004 nan 0.1000 0.0042  
## 8 0.0946 nan 0.1000 0.0054  
## 9 0.0901 nan 0.1000 0.0044  
## 10 0.0854 nan 0.1000 0.0052  
## 20 0.0585 nan 0.1000 0.0017  
## 40 0.0417 nan 0.1000 0.0004  
## 60 0.0374 nan 0.1000 0.0001  
## 80 0.0355 nan 0.1000 -0.0001  
## 100 0.0345 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1357 nan 0.1000 0.0214  
## 2 0.1173 nan 0.1000 0.0166  
## 3 0.1034 nan 0.1000 0.0138  
## 4 0.0914 nan 0.1000 0.0122  
## 5 0.0821 nan 0.1000 0.0099  
## 6 0.0741 nan 0.1000 0.0076  
## 7 0.0674 nan 0.1000 0.0068  
## 8 0.0619 nan 0.1000 0.0057  
## 9 0.0575 nan 0.1000 0.0046  
## 10 0.0543 nan 0.1000 0.0035  
## 20 0.0361 nan 0.1000 0.0010  
## 40 0.0270 nan 0.1000 0.0000  
## 60 0.0243 nan 0.1000 0.0000  
## 80 0.0231 nan 0.1000 -0.0001  
## 100 0.0224 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1450 nan 0.1000 0.0132  
## 2 0.1345 nan 0.1000 0.0100  
## 3 0.1262 nan 0.1000 0.0084  
## 4 0.1187 nan 0.1000 0.0067  
## 5 0.1121 nan 0.1000 0.0065  
## 6 0.1056 nan 0.1000 0.0057  
## 7 0.0997 nan 0.1000 0.0052  
## 8 0.0951 nan 0.1000 0.0041  
## 9 0.0904 nan 0.1000 0.0045  
## 10 0.0862 nan 0.1000 0.0039  
## 20 0.0609 nan 0.1000 0.0013  
## 40 0.0438 nan 0.1000 0.0003  
## 60 0.0397 nan 0.1000 0.0001  
## 80 0.0379 nan 0.1000 0.0000  
## 100 0.0369 nan 0.1000 0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1376 nan 0.1000 0.0211  
## 2 0.1207 nan 0.1000 0.0164  
## 3 0.1066 nan 0.1000 0.0131  
## 4 0.0947 nan 0.1000 0.0114  
## 5 0.0850 nan 0.1000 0.0088  
## 6 0.0770 nan 0.1000 0.0072  
## 7 0.0707 nan 0.1000 0.0066  
## 8 0.0652 nan 0.1000 0.0050  
## 9 0.0612 nan 0.1000 0.0043  
## 10 0.0580 nan 0.1000 0.0027  
## 20 0.0399 nan 0.1000 0.0007  
## 40 0.0307 nan 0.1000 0.0001  
## 60 0.0277 nan 0.1000 0.0000  
## 80 0.0264 nan 0.1000 -0.0000  
## 100 0.0253 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1495 nan 0.1000 0.0124  
## 2 0.1383 nan 0.1000 0.0112  
## 3 0.1296 nan 0.1000 0.0100  
## 4 0.1221 nan 0.1000 0.0070  
## 5 0.1148 nan 0.1000 0.0075  
## 6 0.1087 nan 0.1000 0.0063  
## 7 0.1027 nan 0.1000 0.0059  
## 8 0.0974 nan 0.1000 0.0051  
## 9 0.0926 nan 0.1000 0.0044  
## 10 0.0880 nan 0.1000 0.0046  
## 20 0.0602 nan 0.1000 0.0020  
## 40 0.0426 nan 0.1000 0.0001  
## 60 0.0381 nan 0.1000 -0.0001  
## 80 0.0364 nan 0.1000 0.0000  
## 100 0.0356 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1406 nan 0.1000 0.0232  
## 2 0.1217 nan 0.1000 0.0177  
## 3 0.1063 nan 0.1000 0.0138  
## 4 0.0947 nan 0.1000 0.0118  
## 5 0.0849 nan 0.1000 0.0094  
## 6 0.0770 nan 0.1000 0.0072  
## 7 0.0702 nan 0.1000 0.0062  
## 8 0.0648 nan 0.1000 0.0053  
## 9 0.0612 nan 0.1000 0.0037  
## 10 0.0568 nan 0.1000 0.0037  
## 20 0.0377 nan 0.1000 0.0010  
## 40 0.0285 nan 0.1000 0.0001  
## 60 0.0259 nan 0.1000 0.0001  
## 80 0.0248 nan 0.1000 -0.0001  
## 100 0.0239 nan 0.1000 -0.0000  
##   
## Iter TrainDeviance ValidDeviance StepSize Improve  
## 1 0.1376 nan 0.1000 0.0213  
## 2 0.1202 nan 0.1000 0.0169  
## 3 0.1060 nan 0.1000 0.0143  
## 4 0.0942 nan 0.1000 0.0120  
## 5 0.0848 nan 0.1000 0.0101  
## 6 0.0765 nan 0.1000 0.0082  
## 7 0.0703 nan 0.1000 0.0066  
## 8 0.0646 nan 0.1000 0.0058  
## 9 0.0597 nan 0.1000 0.0043  
## 10 0.0558 nan 0.1000 0.0041  
## 20 0.0383 nan 0.1000 0.0011  
## 40 0.0290 nan 0.1000 0.0001  
## 60 0.0267 nan 0.1000 -0.0001  
## 80 0.0254 nan 0.1000 0.0001  
## 100 0.0245 nan 0.1000 -0.0001

summary(model\_gbm)



## var rel.inf  
## smokeryes smokeryes 50.20481111  
## age age 43.03408083  
## bmi bmi 3.44643814  
## children2 children2 1.51914679  
## children3 children3 0.49239535  
## children4 children4 0.47325561  
## regionsouthwest regionsouthwest 0.33293223  
## regionsoutheast regionsoutheast 0.19470131  
## sexmale sexmale 0.16874375  
## children1 children1 0.09964949  
## children5 children5 0.03384538  
## regionnorthwest regionnorthwest 0.00000000

## xgbLinear

# xgbTuningGrid = expand.grid(nrounds = c(50, 100), lambda = seq(0.1, 0.5, 0.1), alpha = seq(0.1, 0.5, 0.1), eta = c(0.3, 0.4))  
# model\_xgb4 = train(logCharges ~ smoker + bmi + age + children + sex + region, data = train, tuneLength = 3, method = "xgbLinear", trControl = myControl, tuneGrid = xgbTuningGrid)  
  
# model\_xgb4