Final\_Project\_FyonaSun

Fyona Sun

2/10/2020

library(readr)  
auction=read\_csv('./online-auctions-dataset/auction.csv')

## Parsed with column specification:  
## cols(  
## auctionid = col\_double(),  
## bid = col\_double(),  
## bidtime = col\_double(),  
## bidder = col\_character(),  
## bidderrate = col\_double(),  
## openbid = col\_double(),  
## price = col\_double(),  
## item = col\_character(),  
## auction\_type = col\_character()  
## )

head(auction)

## # A tibble: 6 x 9  
## auctionid bid bidtime bidder bidderrate openbid price item auction\_type  
## <dbl> <dbl> <dbl> <chr> <dbl> <dbl> <dbl> <chr> <chr>   
## 1 1638893549 175 2.23 schaden… 0 99 178. Carti… 3 day aucti…  
## 2 1638893549 100 2.60 chuik 0 99 178. Carti… 3 day aucti…  
## 3 1638893549 120 2.60 kiwisst… 2 99 178. Carti… 3 day aucti…  
## 4 1638893549 150 2.60 kiwisst… 2 99 178. Carti… 3 day aucti…  
## 5 1638893549 178. 2.91 eli.fli… 4 99 178. Carti… 3 day aucti…  
## 6 1639453840 1 0.356 bfalconb 2 1 355 Carti… 3 day aucti…

dim(auction)

## [1] 10681 9

sapply(auction, class)

## auctionid bid bidtime bidder bidderrate openbid   
## "numeric" "numeric" "numeric" "character" "numeric" "numeric"   
## price item auction\_type   
## "numeric" "character" "character"

The data set includes 10681 observations and 9 variables auctionid: unique identifier of an auction bid: the proxy bid placed by a bidder bidtime: the time in days that the bid was placed, from the start of the auction bidder: eBay username of the bidder bidderrate: eBay feedback rating of the bidder openbid: the opening bid set by the seller price: the closing price that the item sold for (equivalent to the second highest bid + an increment) item: auction item auction\_type

Understanding eBay auction policy It’s important to understand how eBay auction policy works before conducting further analysis. I found this explanation easy to understand.

The website helps to answer the following questions:

What’s the relationship between bids and bidtime? Poeple have to bid higher than current price, which is the second highest bid+increment. If someone places a bid much higher than current price, eBay will only use part of his/her bid(second highest bid+increment) as the new current price. People can bid as long as their bid is higher than current price. Therefore, as bidtime increases, we sometimes see bids that are lower than previous bids. People will be notified when they are outbid, so they may increase their max bids to remain the higher bidder.

What’s the relationship between bids and closing price? Closing price=second highest bid+increment or highest bid in some cases when second highest bid+increment is greater than the thrid highest bid. For example, if third highest bid is 8 and second highest bid is 10, you can bid 10.01 and if no one’s bid is higher than yours, you get the item by paying 10.01 instead of 10+increment(which is 10.5)

Person who placed the highest bid gets the item but how much he/she needs to pay in most cases depends on the second highest bid. ## Exploring the dataset

## function bid.incr(price)  
bid.incr <-   
 function(price)   
 { bidint <- c(0,0.99,4.99,24.99,99.99,249.99,499.99,999.99,2499.99,4999.99)  
 ## interval of prices  
 inc <- c(0.05,0.25,0.5,1,2.5,5,10,25,50,100)  
 ## increments of price for particular interval  
 inc[findInterval(price,bidint)]  
 }  
############################################################  
########## make livebids ###########  
############################################################  
  
## function recover.livebids(bids,bidder,openbid,winningbid)  
## This function reconstructs the sequence of livebids by   
## inputing the raw bids,bidder IDs and opening bid  
  
recover.livebids <-   
 function(bids,bidder,openbid,winningbid)  
 { nbid <- length(bids)  
 if (nbid==1) { live <- openbid  
 live  
 }  
 else {  
 if (nbid==2) {live <- numeric(nbid)  
 live[1] <- openbid  
 live[nbid] <- winningbid  
 live}  
  
 else { live <- numeric(nbid)  
 maxbid <- bids[1]  
 live[1] <- openbid  
 live[nbid] <- winningbid  
 currentprice <- bids[1]  
 maxbidder <- bidder[1]  
 for (i in 2:(nbid-1))   
 { newbid <- bids[i]  
 newbidder <- bidder[i]  
 if (newbid > maxbid) { if (!(identical(newbidder,maxbidder)))   
 { incr <- bid.incr(maxbid)  
 if (newbid < maxbid+incr) currentprice <- newbid  
 else currentprice <- maxbid+incr  
 maxbid <- newbid   
 maxbidder <- newbidder  
 }   
 else {maxbid <- newbid   
 maxbidder <- maxbidder  
 }  
 }  
 else {if (newbid < maxbid) { incr <- bid.incr(newbid)  
 if (newbid+incr>=maxbid) currentprice <- maxbid  
 else currentprice <- newbid+incr  
 maxbid <- maxbid  
 maxbidder <- maxbidder  
 }  
 else { if (!(identical(newbidder,maxbidder)))   
 {currentprice <- maxbid  
 maxbid <- maxbid  
 maxbidder <- maxbidder  
 }  
 else {currentprice <- currentprice  
 maxbid <- maxbid  
 maxbidder <- maxbidder  
 }   
 }  
 }  
 live[i] <- currentprice  
 }  
 live  
 }  
 }  
 }

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## price = col\_double(),  
## item = col\_character(),  
## auction\_type = col\_character()  
## )

swarovski=read\_csv('./online-auctions-dataset/swarovski.csv')

## Parsed with column specification:  
## cols(  
## Seller = col\_double(),  
## Bidder = col\_double(),  
## Weight = col\_double(),  
## Bidder.Volume = col\_double(),  
## Seller.Volume = col\_double()  
## )

head(auction)

## # A tibble: 6 x 9  
## auctionid bid bidtime bidder bidderrate openbid price item auction\_type  
## <dbl> <dbl> <dbl> <chr> <dbl> <dbl> <dbl> <chr> <chr>   
## 1 1638893549 175 2.23 schaden… 0 99 178. Carti… 3 day aucti…  
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## 6 1639453840 1 0.356 bfalconb 2 1 355 Carti… 3 day aucti…

head(swarovski)

## # A tibble: 6 x 5  
## Seller Bidder Weight Bidder.Volume Seller.Volume  
## <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 332874919 718577508 2 3 547  
## 2 594667804 399983466 5 6 183  
## 3 663070601 655828811 1 4 274  
## 4 309608641 599835541 3 8 3986  
## 5 201729374 693022555 1 2 4681  
## 6 332874919 622536435 2 4 547

dim(auction)

## [1] 10681 9

dim(swarovski)

## [1] 200 5

summary(auction)

## auctionid bid bidtime bidder   
## Min. :1.639e+09 Min. : 0.01 Min. :0.000567 Length:10681   
## 1st Qu.:3.015e+09 1st Qu.: 72.00 1st Qu.:1.949931 Class :character   
## Median :3.021e+09 Median : 140.00 Median :4.140833 Mode :character   
## Mean :4.136e+09 Mean : 207.59 Mean :3.979628   
## 3rd Qu.:8.212e+09 3rd Qu.: 210.00 3rd Qu.:6.448060   
## Max. :8.216e+09 Max. :5400.00 Max. :6.999990   
##   
## bidderrate openbid price item   
## Min. : -4.00 Min. : 0.01 Min. : 26.0 Length:10681   
## 1st Qu.: 1.00 1st Qu.: 1.00 1st Qu.: 186.5 Class :character   
## Median : 5.00 Median : 4.99 Median : 228.5 Mode :character   
## Mean : 31.94 Mean : 52.25 Mean : 335.0   
## 3rd Qu.: 21.00 3rd Qu.: 50.00 3rd Qu.: 255.0   
## Max. :3140.00 Max. :5000.00 Max. :5400.0   
## NA's :11   
## auction\_type   
## Length:10681   
## Class :character   
## Mode :character   
##   
##   
##   
##

summary(swarovski)

## Seller Bidder Weight Bidder.Volume   
## Min. : 24273 Min. : 221355 Min. : 1.000 Min. : 1.00   
## 1st Qu.: 94870114 1st Qu.: 80389757 1st Qu.: 1.000 1st Qu.: 4.00   
## Median :201729374 Median :191077522 Median : 2.000 Median : 6.00   
## Mean :198089751 Mean :276467688 Mean : 3.085 Mean : 9.26   
## 3rd Qu.:309608641 3rd Qu.:449791350 3rd Qu.: 3.000 3rd Qu.:11.00   
## Max. :663070601 Max. :723365710 Max. :56.000 Max. :94.00   
## Seller.Volume   
## Min. : 2.0   
## 1st Qu.: 382.5   
## Median :1791.0   
## Mean :1966.3   
## 3rd Qu.:3986.0   
## Max. :4681.0

levels(as.factor(auction$item))

## [1] "Cartier wristwatch" "Palm Pilot M515 PDA" "Xbox game console"

#"Cartier wristwatch" "Palm Pilot M515 PDA" "Xbox game console"   
levels(as.factor(auction$auction\_type))

## [1] "3 day auction" "5 day auction" "7 day auction"

#"3 day auction" "5 day auction" "7 day auction"

## data manipulation

library(tidyverse)

## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.0 ──

## ✓ ggplot2 3.3.0 ✓ dplyr 0.8.5  
## ✓ tibble 2.1.3 ✓ stringr 1.4.0  
## ✓ tidyr 1.0.2 ✓ forcats 0.5.0  
## ✓ purrr 0.3.3

## ── Conflicts ────────────────────────────────────────── tidyverse\_conflicts() ──  
## x dplyr::filter() masks stats::filter()  
## x dplyr::lag() masks stats::lag()

library(zoo)

##   
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':  
##   
## as.Date, as.Date.numeric

#change characteristic varibale to dummy variables  
auction$is\_3day<- ifelse(auction$auction\_type=='3 day auction',1,0)  
auction$is\_5day<- ifelse(auction$auction\_type=='5 day auction',1,0)  
auction$is\_7day<- ifelse(auction$auction\_type=='7 day auction',1,0)  
auction$is\_catier<- ifelse(auction$item=='Cartier wristwatch',1,0)  
auction$is\_palm<- ifelse(auction$item=='Palm Pilot M515 PDA',1,0)  
auction$is\_xbox<- ifelse(auction$item=='Xbox game console',1,0)  
#add a few statistical variables  
## winning bid, number of bids & average bid per auction  
u<-unique(auction$auctionid)  
winner<-rep(0,nrow(auction))  
livebid<- rep(0,nrow(auction))  
average<-rep(0,nrow(auction))  
sd<- rep(0,nrow(auction))  
num.bids<-rep(0,nrow(auction))  
  
for (i in u){  
 indexes<-which(auction$auctionid == i)  
 cur.average<-sum(auction$bid[indexes])/length(indexes)  
 cur.dev<- sd(auction$bid[indexes])  
 current<- recover.livebids(auction$bid[indexes],auction$bidder[indexes],auction$openbid[indexes],auction$price[indexes])  
 j<-0  
 for (k in indexes){  
 j<- j+1  
 winner[k]<-ifelse(auction$bid[k]==auction$price[k], 1 , 0)  
 num.bids[k]<-length(indexes)  
 average[k]<-cur.average  
 sd[k]<- cur.dev  
 livebid[k]<- current[j]  
 }  
  
}

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auction$winner<-winner  
auction$avg.bid<-average  
auction$sd.bid<- sd  
auction$num.bids<-num.bids  
auction$livebid<- livebid  
  
## length of auction (number of days)  
auction$length<-rep(0,nrow(auction))  
idx3<-which(auction$auction\_type == "3 day auction")  
auction$length[idx3]<-3  
idx5<-which(auction$auction\_type == "5 day auction")  
auction$length[idx5]<-5  
idx7<-which(auction$auction\_type == "7 day auction")  
auction$length[idx7]<-7  
  
## normalized bidding time (when bid was placed over auction length)  
auction$time.fraction<-auction$bidtime/auction$length  
  
## normalized bidding price (bid over winning price)  
auction$bid.fraction<-auction$bid/auction$price  
  
## bid distance from open bid  
auction<-mutate(auction,dist.open=(bid-openbid)/bid)  
  
## bid distance from average bid  
auction<-mutate(auction,dist.avg=(bid-avg.bid)/avg.bid)  
  
## add sequence of each bid  
auction$num\_current\_bids <- ave(auction$bidtime, auction$auctionid, FUN = seq\_along)  
  
## add time difference  
auction$time.diff <- ave(auction$bidtime, auction$auctionid, FUN = function(x) c(0,diff(x)))  
auction$time.diff[is.na(auction$time.diff)]<- 0   
  
## add bid difference  
auction$bid.diff <- ave(auction$bid, auction$auctionid, FUN = function(x) c(0,diff(x)))  
auction$bid.diff[is.na(auction$bid.diff)]<- 0   
  
## add bid velocity  
auction$velocity<- auction$bid.diff/auction$time.diff  
auction$velocity[is.infinite(auction$velocity)]<- 0   
auction$velocity[is.nan(auction$velocity)]<- 0   
  
##add lag  
auction$livebid.lag<- ave(auction$livebid, factor(auction$auctionid), FUN=function(x) c(NA,x[1:(length(x)-1)]))

## Warning in x[i] <- value[[j]]: number of items to replace is not a multiple of  
## replacement length

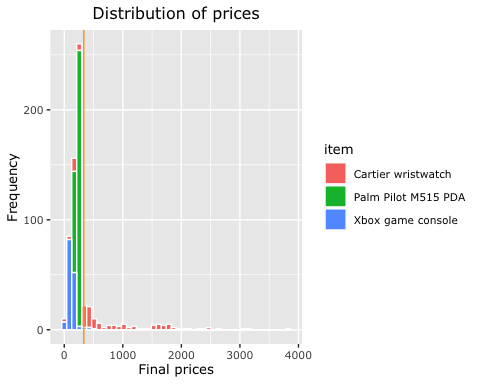
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auction$livebid.lag<- na.fill(auction$livebid.lag,0)

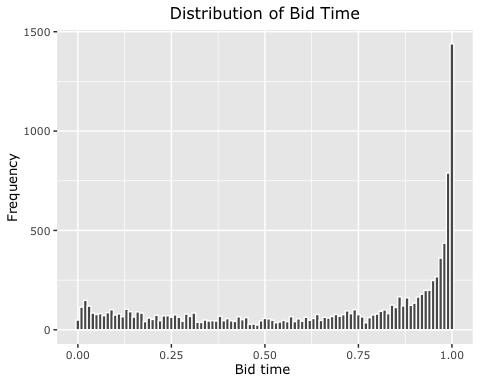
## Exploring the data

There are 627 item in the data set in total. Since the bidders do not know what others have bid and might be placing mulptiple bids after being notified that they were outbid, the last bid is not necessaily the one who get the item.

library(dplyr)  
#get rid of the outlier  
#1639672910  
auction<-auction[auction$auctionid!="1639672910",]  
  
closing\_price<- auction %>% select(auctionid,openbid,price,auction\_type,item)%>%  
 group\_by(auction$auctionid) %>%   
 summarise(openbid=max(openbid),price=max(price),auction\_type=max(auction\_type),item=max(item))  
# text theme for every plot in this project  
text\_theme <- theme(text = element\_text(size = 10,   
 family = "Verdana",   
 face = "plain"),  
 plot.title = element\_text(hjust = 0.5))  
  
# distribution of prices  
ggplot(closing\_price,   
 aes(x = price)) +   
 geom\_histogram(binwidth = 85,   
 aes(fill = item),   
 col = "white") +  
 geom\_vline(aes(xintercept = mean(auction$price)),   
 col = "orange",  
 size = 0.5) +  
 labs(title = "Distribution of prices",  
 x = "Final prices",  
 y = "Frequency") +  
 text\_theme

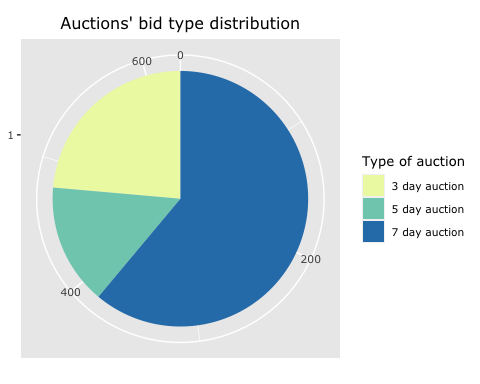


ggplot(auction,   
 aes(x = time.fraction)) +   
 geom\_histogram(binwidth = 0.01,  
 col = "white") +  
 labs(title = "Distribution of Bid Time",  
 x = "Bid time ",  
 y = "Frequency") +  
 text\_theme

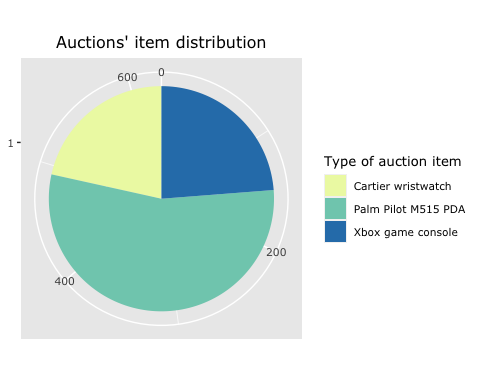


# distribution of auction types  
ggplot(closing\_price,   
 aes(x = factor(1),   
 fill = closing\_price$auction\_type)) +  
 geom\_bar(width = 3) +  
 ggtitle("Auctions' bid type distribution") +  
 coord\_polar(theta = "y") +  
 labs(fill= "Type of auction") +  
 scale\_fill\_brewer(palette = "YlGnBu") +  
 xlab(NULL) + ylab(NULL) +  
 text\_theme

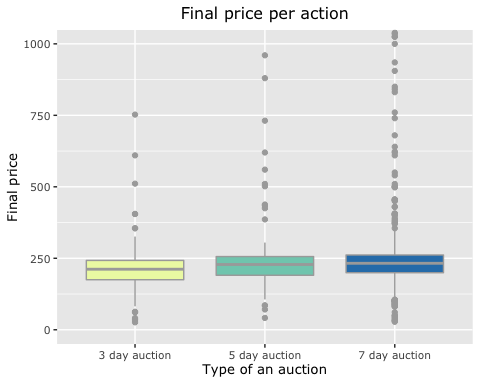
## Warning: Use of `closing\_price$auction\_type` is discouraged. Use `auction\_type`  
## instead.



# few ggplot complements   
bar\_auction\_type <- geom\_bar(aes(fill = auction$auction\_type),   
 stat = "count")  
  
ggplot(closing\_price,   
 aes(x = factor(1),   
 fill = item)) +  
 geom\_bar(width = 3) +  
 ggtitle("Auctions' item distribution") +  
 coord\_polar(theta = "y") +  
 labs(fill= "Type of auction item") +  
 scale\_fill\_brewer(palette = "YlGnBu") +  
 xlab(NULL) + ylab(NULL) +  
 text\_theme



# few ggplot complements   
bar\_auction\_type <- geom\_bar(aes(fill = auction$auction\_type),   
 stat = "count")  
  
# relationship between final price per auction and auction type  
ggplot(closing\_price,   
 aes(x = auction\_type, y = price)) +   
 geom\_boxplot(aes(fill = auction\_type),   
 color = "darkgrey") +  
 labs(title = "Final price per action",   
 x = "Type of an auction",   
 y = "Final price") +  
 guides(fill = F) +  
 scale\_fill\_brewer(palette = "YlGnBu") +   
 text\_theme +   
 coord\_cartesian(ylim = c(0, 1000)) # few outliers masked



## data manipulation

library(tidyverse)  
library(zoo)  
#change characteristic varibale to dummy variables  
auction$is\_3day<- ifelse(auction$auction\_type=='3 day auction',1,0)  
auction$is\_5day<- ifelse(auction$auction\_type=='5 day auction',1,0)  
auction$is\_7day<- ifelse(auction$auction\_type=='7 day auction',1,0)  
auction$is\_catier<- ifelse(auction$item=='Cartier wristwatch',1,0)  
auction$is\_palm<- ifelse(auction$item=='Palm Pilot M515 PDA',1,0)  
auction$is\_xbox<- ifelse(auction$item=='Xbox game console',1,0)  
#add a few statistical variables  
## winning bid, number of bids & average bid per auction  
u<-unique(auction$auctionid)  
winner<-rep(0,nrow(auction))  
livebid<- rep(0,nrow(auction))  
average<-rep(0,nrow(auction))  
sd<- rep(0,nrow(auction))  
num.bids<-rep(0,nrow(auction))  
  
for (i in u){  
 indexes<-which(auction$auctionid == i)  
 cur.average<-sum(auction$bid[indexes])/length(indexes)  
 cur.dev<- sd(auction$bid[indexes])  
 current<- recover.livebids(auction$bid[indexes],auction$bidder[indexes],auction$openbid[indexes],auction$price[indexes])  
 j<-0  
 for (k in indexes){  
 j<- j+1  
 winner[k]<-ifelse(auction$bid[k]==auction$price[k], 1 , 0)  
 num.bids[k]<-length(indexes)  
 average[k]<-cur.average  
 sd[k]<- cur.dev  
 livebid[k]<- current[j]  
 }  
  
}

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auction$winner<-winner  
auction$avg.bid<-average  
auction$sd.bid<- sd  
auction$num.bids<-num.bids  
auction$livebid<- livebid  
  
## length of auction (number of days)  
auction$length<-rep(0,nrow(auction))  
idx3<-which(auction$auction\_type == "3 day auction")  
auction$length[idx3]<-3  
idx5<-which(auction$auction\_type == "5 day auction")  
auction$length[idx5]<-5  
idx7<-which(auction$auction\_type == "7 day auction")  
auction$length[idx7]<-7  
  
## normalized bidding time (when bid was placed over auction length)  
auction$time.fraction<-auction$bidtime/auction$length  
  
## normalized bidding price (bid over winning price)  
auction$bid.fraction<-auction$bid/auction$price  
  
## bid distance from open bid  
auction<-mutate(auction,dist.open=(bid-openbid)/bid)  
  
## bid distance from average bid  
auction<-mutate(auction,dist.avg=(bid-avg.bid)/avg.bid)  
  
## add sequence of each bid  
auction$num\_current\_bids <- ave(auction$bidtime, auction$auctionid, FUN = seq\_along)  
  
## add time difference  
auction$time.diff <- ave(auction$bidtime, auction$auctionid, FUN = function(x) c(0,diff(x)))  
auction$time.diff[is.na(auction$time.diff)]<- 0   
  
## add bid difference  
auction$bid.diff <- ave(auction$bid, auction$auctionid, FUN = function(x) c(0,diff(x)))  
auction$bid.diff[is.na(auction$bid.diff)]<- 0   
  
## add bid velocity  
auction$velocity<- auction$bid.diff/auction$time.diff  
auction$velocity[is.infinite(auction$velocity)]<- 0   
auction$velocity[is.nan(auction$velocity)]<- 0   
  
##add lag  
auction$livebid.lag<- ave(auction$livebid, factor(auction$auctionid), FUN=function(x) c(NA,x[1:(length(x)-1)]))

## Warning in x[i] <- value[[j]]: number of items to replace is not a multiple of  
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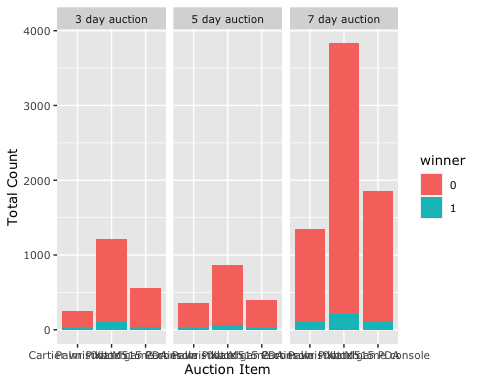
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auction$livebid.lag<- na.fill(auction$livebid.lag,0)

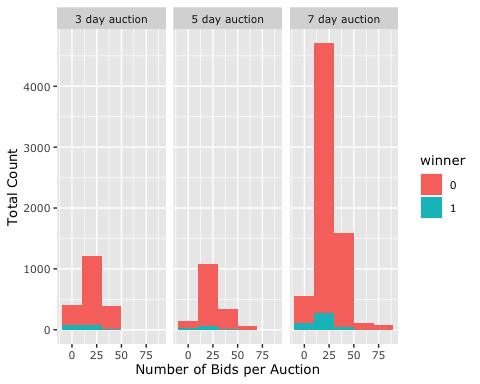
head(auction,50)

## # A tibble: 50 x 30  
## auctionid bid bidtime bidder bidderrate openbid price item auction\_type  
## <dbl> <dbl> <dbl> <chr> <dbl> <dbl> <dbl> <chr> <chr>   
## 1 1.64e9 175 2.23 schad… 0 99 178. Cart… 3 day aucti…  
## 2 1.64e9 100 2.60 chuik 0 99 178. Cart… 3 day aucti…  
## 3 1.64e9 120 2.60 kiwis… 2 99 178. Cart… 3 day aucti…  
## 4 1.64e9 150 2.60 kiwis… 2 99 178. Cart… 3 day aucti…  
## 5 1.64e9 178. 2.91 eli.f… 4 99 178. Cart… 3 day aucti…  
## 6 1.64e9 1 0.356 bfalc… 2 1 355 Cart… 3 day aucti…  
## 7 1.64e9 1.25 0.485 sbord 1 1 355 Cart… 3 day aucti…  
## 8 1.64e9 1.5 0.493 bfalc… 2 1 355 Cart… 3 day aucti…  
## 9 1.64e9 25 0.495 sbord 1 1 355 Cart… 3 day aucti…  
## 10 1.64e9 2 0.511 bfalc… 2 1 355 Cart… 3 day aucti…  
## # … with 40 more rows, and 21 more variables: is\_3day <dbl>, is\_5day <dbl>,  
## # is\_7day <dbl>, is\_catier <dbl>, is\_palm <dbl>, is\_xbox <dbl>, winner <dbl>,  
## # avg.bid <dbl>, sd.bid <dbl>, num.bids <dbl>, livebid <dbl>, length <dbl>,  
## # time.fraction <dbl>, bid.fraction <dbl>, dist.open <dbl>, dist.avg <dbl>,  
## # num\_current\_bids <dbl>, time.diff <dbl>, bid.diff <dbl>, velocity <dbl>,  
## # livebid.lag <dbl>

auction$winner<-as.factor(auction$winner)  
######## PLOTS  
# text theme for every plot in this project  
text\_theme <- theme(text = element\_text(size = 10,   
 family = "Verdana",   
 face = "plain"),  
 plot.title = element\_text(hjust = 0.5))  
  
# distribution of bids over item and aution type  
ggplot(auction,aes(x =item, fill= winner))+  
 geom\_bar()+  
 facet\_wrap(~auction\_type)+  
 xlab("Auction Item")+ ylab("Total Count")+  
 text\_theme



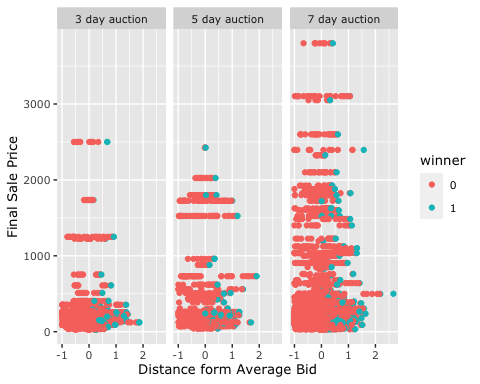
# check if no. of bids has predictive power  
# hypothesis - As number of bids per item increases chance of winning drops  
  
ggplot(auction,aes(x = num.bids, fill= winner))+  
 geom\_histogram(binwidth = 20)+  
 facet\_wrap(~auction\_type)+  
 xlab("Number of Bids per Auction")+ ylab("Total Count")+  
 text\_theme



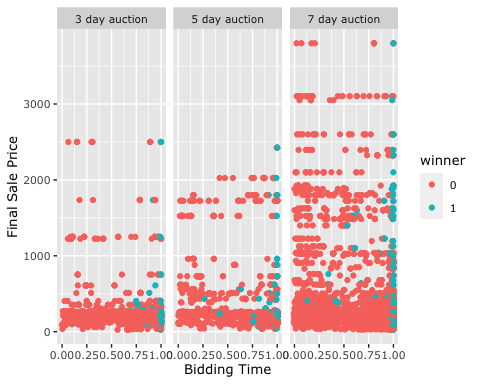
# check if distance from open bid has predictive power  
# hypothesis - Bids much higher than openning bid have higher chance of winning  
ggplot(auction)+  
 geom\_point(aes(x = dist.open,y=price, color= winner))+  
 facet\_wrap(~auction\_type)+  
 xlab("Distance form Openning Bid")+ ylab("Final Sale Price")+  
 text\_theme



# check if distance from average bid has predictive power  
# hypothesis - Bids below the average bid have zero chance of winning  
  
ggplot(auction)+  
 geom\_point(aes(x =dist.avg,y=price, color= winner))+  
 facet\_wrap(~auction\_type)+  
 xlab("Distance form Average Bid")+ ylab("Final Sale Price")+  
 text\_theme

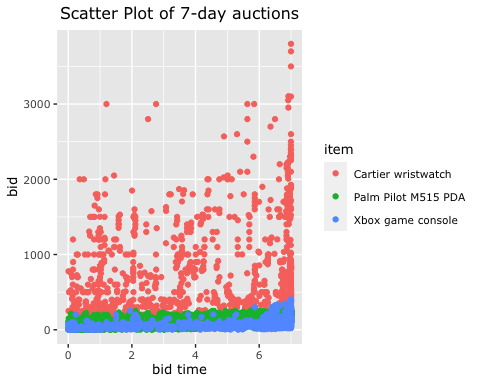


# check if time fraction has predictive power  
# hypothesis - Bids placed toward the end of the auction have higher chance of winning  
  
ggplot(auction)+  
 geom\_point(aes(x =time.fraction,y=price, color= winner))+  
 facet\_wrap(~auction\_type)+  
 xlab("Bidding Time")+ ylab("Final Sale Price")+  
 text\_theme

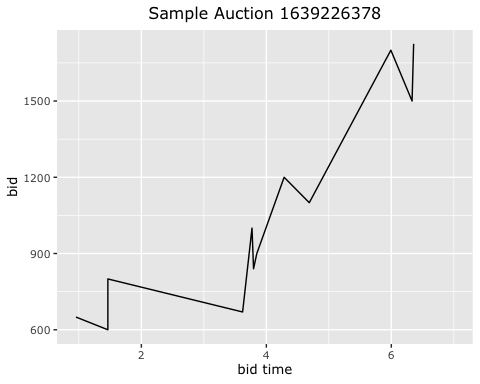


### modeling a single auction using Smoothing splines

#Example of a 7-day auction  
sevenday<- auction[which(auction$length==7),]  
ggplot(sevenday, aes(x=bidtime, y=bid, color= item)) +  
 geom\_point() +   
 scale\_fill\_brewer(palette = "YlGnBu") +   
 xlab("bid time") +  
 ggtitle("Scatter Plot of 7-day auctions")+  
 expand\_limits(x=7)+  
 text\_theme



sample3<- auction[which(auction$auctionid=='1639226378'),]  
ggplot(sample3, aes(x=bidtime, y=bid)) +  
 geom\_line() +   
 xlab("bid time") +  
 ggtitle("Sample Auction 1639226378")+  
 expand\_limits(x=7)+  
 text\_theme



## model one singel auction using non-linear polunomial regression

library(splines)  
library(gam)

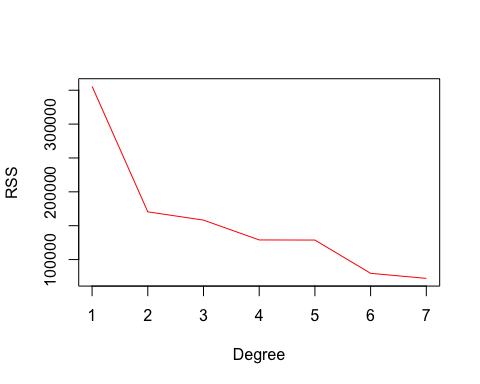
## Loading required package: foreach

##   
## Attaching package: 'foreach'

## The following objects are masked from 'package:purrr':  
##   
## accumulate, when

## Loaded gam 1.16.1

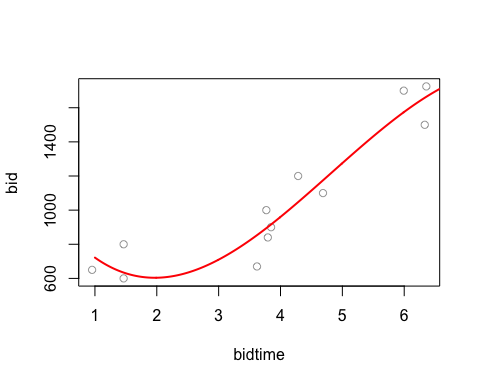
rss <- rep(0, 7)  
for (i in 1:7) {  
 fit <- lm(bid ~ poly(bidtime, i), data = sample3)  
 rss[i] <- sum(fit$residuals^2)  
}  
plot(1:7, rss, xlab = "Degree", ylab = "RSS", type = "l", col='red')



fit.lm <- lm(bid ~ poly(bidtime,3), data = sample3)  
summary(fit.lm)

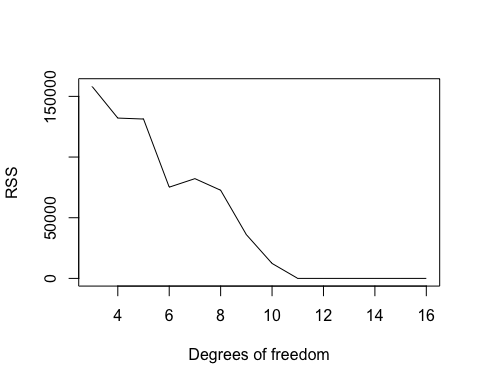
##   
## Call:  
## lm(formula = bid ~ poly(bidtime, 3), data = sample3)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -183.30 -77.02 -25.10 110.84 165.86   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 1057.1 40.6 26.039 5.08e-09 \*\*\*  
## poly(bidtime, 3)1 1178.1 140.6 8.377 3.13e-05 \*\*\*  
## poly(bidtime, 3)2 430.3 140.6 3.060 0.0156 \*   
## poly(bidtime, 3)3 -110.7 140.6 -0.787 0.4540   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 140.6 on 8 degrees of freedom  
## Multiple R-squared: 0.9093, Adjusted R-squared: 0.8752   
## F-statistic: 26.72 on 3 and 8 DF, p-value: 0.0001607

bidtime.new <- seq(1, 7, by = 0.01)  
pred <- predict(fit.lm, list(bidtime = bidtime.new))  
plot(bid ~ bidtime, data = sample3, col = "darkgrey")  
lines(bidtime.new,pred, col = "red", lwd = 2)

 The RSS decreases as the degree of the polynomial decreases. It achieves its minimum at degree 7. However, it diverges as the degree of polynomial increases. Thus from the plot we choose the degree of 3.

## Soomthing splines and gam

rss <- rep(0, 16)  
for (i in 3:16) {  
 fit <- lm(bid ~ bs(bidtime, df = i), data = sample3)  
 rss[i] <- sum(fit$residuals^2)  
}  
plot(3:16, rss[-c(1, 2)], xlab = "Degrees of freedom", ylab = "RSS", type = "l")



fit.spline <- lm( bid~ bs(bidtime, knots = c(5, 14)), data = sample3)  
summary(fit.spline)

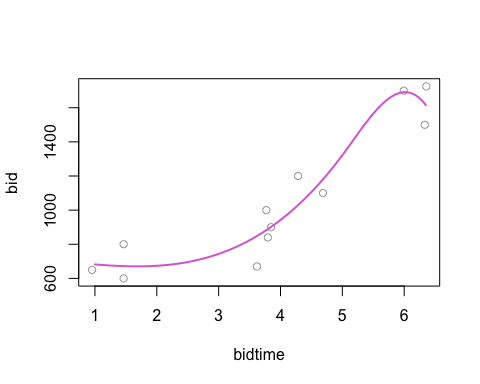
##   
## Call:  
## lm(formula = bid ~ bs(bidtime, knots = c(5, 14)), data = sample3)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -178.36 -74.05 -17.51 114.28 170.18   
##   
## Coefficients: (1 not defined because of singularities)  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 683.35 130.03 5.255 0.001179 \*\*   
## bs(bidtime, knots = c(5, 14))1 -41.55 506.34 -0.082 0.936893   
## bs(bidtime, knots = c(5, 14))2 -10.57 303.66 -0.035 0.973216   
## bs(bidtime, knots = c(5, 14))3 1150.59 312.44 3.683 0.007833 \*\*   
## bs(bidtime, knots = c(5, 14))4 928.39 161.69 5.742 0.000704 \*\*\*  
## bs(bidtime, knots = c(5, 14))5 NA NA NA NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 138.5 on 7 degrees of freedom  
## Multiple R-squared: 0.923, Adjusted R-squared: 0.879   
## F-statistic: 20.97 on 4 and 7 DF, p-value: 0.0005362

pred.spline <- predict(fit.spline, list(bidtime = bidtime.new))

## Warning in bs(bidtime, degree = 3L, knots = c(5, 14), Boundary.knots =  
## c(0.954039352, : some 'x' values beyond boundary knots may cause ill-conditioned  
## bases

## Warning in predict.lm(fit.spline, list(bidtime = bidtime.new)): prediction from  
## a rank-deficient fit may be misleading

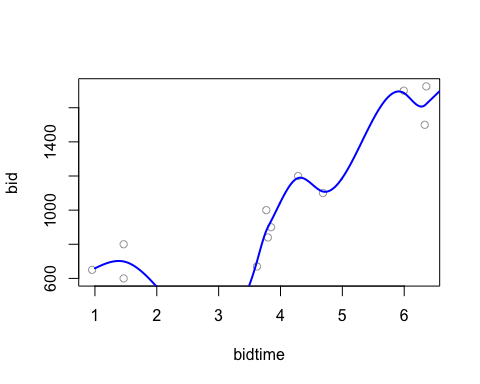
plot(bid ~ bidtime, data = sample3, col = "darkgrey")  
lines(bidtime.new, pred.spline, col = "orchid", lwd = 2)



bid<- sample3$bid  
bidtime<- sample3$bidtime  
fit.sspline <- smooth.spline(bid, bidtime,df=3)  
fit.gam<- gam(bid ~ s(bidtime,7))

## Warning in model.matrix.default(mt, mf, contrasts): non-list contrasts argument  
## ignored

pred.sspline<- predict(fit.sspline, bidtime.new)  
pred.gam <- predict(fit.gam, list(bidtime = bidtime.new))  
plot(bid ~ bidtime, data = sample3, col = "darkgrey")  
lines(bidtime.new,pred.sspline$y, col = "red", lwd = 2)  
lines(bidtime.new,pred.gam, col = "blue", lwd = 2)

 ## Add bidding pattern

#split by auction  
duration<-1  
sLive <- split(auction$livebid,auction$auctionid)  
sTime <- split(auction$time.fraction,auction$auctionid)  
#create variables with opening and closing bid added  
numauct<-length(sLive)  
sLiveEnds<-list(0);length(sLiveEnds)<-numauct  
sTimeEnds<-list(0); length(sTimeEnds)<-numauct  
sLiveStart<-list(0); length(sLiveStart)<-numauct  
sTimeStart<-list(0); length(sTimeStart)<-numauct  
sTimeEndsTemp<-list(0); length(sTimeStart)<-numauct  
sTimeStartTemp<-list(0); length(sTimeStartTemp)<-numauct  
for (j in 1:numauct){  
 sLiveEnds[[j]]<-c(min(sLive[[j]]),sLive[[j]],max(sLive[[j]]))  
 sTimeEnds[[j]]<-c(0,sTime[[j]],duration)  
 sLiveStart[[j]]<-c(min(sLive[[j]]),sLive[[j]])  
 sTimeStart[[j]]<-c(0,sTime[[j]])  
 sTimeEndsTemp[[j]]<-c(0.000001,sTime[[j]],duration)  
 sTimeStartTemp[[j]]<-c(0.000001,sTime[[j]])  
 }  
  
delta<- 0.01  
epsilon<-0.000001  
num.mod<-4 ##number of models  
w.x<-.5  
w.y<-.5  
  
  
########################  
##SSE for Diffent Models  
########################  
n<-length(sLive) ##number of auctions I'm looking at   
wSSE.range<-array(0,c(n,num.mod))   
wSSE.var<-array(0,c(n,num.mod))   
models.range<-array(0,n)  
models.var<-array(0,n)  
  
for (i in 1:n){  
  
## Exponential Model (Model 1)  
x<-seq(0,duration,by=.01)  
reg1<-lm(log(sLiveEnds[[i]])~ sTimeEnds[[i]])  
fit1y<-exp(as.vector(reg1$coefficients)[1])\*exp(as.vector(reg1$coefficients)[2]\*sTimeEnds[[i]])  
fit1x<-log(sLiveEnds[[i]]/exp(as.vector(reg1$coefficients)[1]))/as.vector(reg1$coefficients)[2]  
fit1.SSEy<- sum((fit1y-sLiveEnds[[i]])^2)  
fit1.SSEx<- sum((fit1x-sTimeEnds[[i]])^2)  
wSSE.range[i,1]<- (w.y\*fit1.SSEy)/diff(range(sLive[[i]]))^2 + (w.x\*fit1.SSEx)/diff(range(sTimeEnds[[i]]))^2  
wSSE.var[i,1]<- (w.y\*fit1.SSEy)/var(sLive[[i]]) + (w.x\*fit1.SSEx)/var(sTimeEnds[[i]])  
  
## Invere Exponential Model (Model 2)   
x<-seq(0,max(sLive[[i]]),by=.1)  
reg2<-lm(log(sTimeEndsTemp[[i]])~ sLiveEnds[[i]])  
fit2y<-log(sTimeEndsTemp[[i]]/exp(as.vector(reg2$coefficients)[1])) /as.vector(reg2$coefficients)[2]  
fit2x<-exp(as.vector(reg2$coefficients)[1]) \* exp(as.vector(reg2$coefficients)[2]\*sLiveEnds[[i]])  
fit2.SSEy<- sum((fit2y-sLiveEnds[[i]])^2)  
fit2.SSEx<- sum((fit2x-sTimeEnds[[i]])^2)  
wSSE.range[i,2]<- (w.y\*fit2.SSEy)/diff(range(sLive[[i]]))^2 + (w.x\*fit2.SSEx)/diff(range(sTimeEnds[[i]]))^2  
wSSE.var[i,2]<- (w.y\*fit2.SSEy)/var(sLive[[i]]) + (w.x\*fit2.SSEx)/var(sTimeEnds[[i]])  
  
## Logistic Growth (Model 3)   
x<-seq(0,duration,by=.01)  
reg3<- lm( log((max(sLiveStart[[i]])+delta)/sLiveStart[[i]]-1) ~ sTimeStart[[i]] )  
fit3y<- (max(sLiveEnds[[i]])+delta)/(1+exp(as.vector(reg3$coefficients)[1])\*exp(as.vector(reg3$coefficients)[2]\*sTimeEnds[[i]]))  
fit3x<- (log( (max(sLiveEnds[[i]])+delta)/sLiveEnds[[i]] - 1) - log (exp(as.vector(reg3$coefficients)[1])))/as.vector(reg3$coefficients)[2]  
fit3.SSEy<- sum((fit3y-sLiveEnds[[i]])^2)  
fit3.SSEx<- sum((fit3x-sTimeEnds[[i]])^2)  
wSSE.range[i,3]<- (w.y\*fit3.SSEy)/diff(range(sLive[[i]]))^2 + (w.x\*fit3.SSEx)/diff(range(sTimeEnds[[i]]))^2  
wSSE.var[i,3]<- (w.y\*fit3.SSEy)/var(sLive[[i]]) + (w.x\*fit3.SSEx)/var(sTimeEnds[[i]])  
  
## Inverse Logistic Growth (Model 4)  
x<-seq(0,max(sLive[[i]]),by=.1)  
reg4<- lm( log((duration+epsilon)/sTimeEndsTemp[[i]]-1) ~ sLiveEnds[[i]])  
fit4y<- (log(((duration+epsilon)/sTimeEndsTemp[[i]])-1) - as.vector(reg4$coefficients)[1]) /as.vector(reg4$coefficients)[2]  
fit4x<- (duration+epsilon)/(1+exp(as.vector(reg4$coefficients)[1])\*exp(as.vector(reg4$coefficients)[2]\*sLiveEnds[[i]]))  
fit4.SSEy<- sum((fit4y-sLiveEnds[[i]])^2)  
fit4.SSEx<- sum((fit4x-sTimeEnds[[i]])^2)  
wSSE.range[i,4]<- (w.y\*fit4.SSEy)/diff(range(sLive[[i]]))^2 + (w.x\*fit4.SSEx)/diff(range(sTimeEnds[[i]]))^2  
wSSE.var[i,4]<- (w.y\*fit4.SSEy)/var(sLive[[i]]) + (w.x\*fit4.SSEx)/var(sTimeEnds[[i]])  
  
}

for (k in 1:n){  
 wSSE.range[k,][wSSE.range[k,]=="NaN"]=(min(na.omit(wSSE.range[k,])+1))  
 wSSE.var[k,][wSSE.var[k,]=="NaN"]=(min(na.omit(wSSE.var[k,])+1))  
 models.range[k]<-(1:num.mod)[min(wSSE.range[k,])==wSSE.range[k,]]  
 models.var[k]<-(1:num.mod)[min(wSSE.var[k,])==wSSE.var[k,]]  
}

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
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## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
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## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

## Warning in min(na.omit(wSSE.var[k, ]) + 1): no non-missing arguments to min;  
## returning Inf

## Warning in models.range[k] <- (1:num.mod)[min(wSSE.range[k, ]) ==  
## wSSE.range[k, : number of items to replace is not a multiple of replacement  
## length

## Warning in models.var[k] <- (1:num.mod)[min(wSSE.var[k, ]) == wSSE.var[k, :  
## number of items to replace is not a multiple of replacement length

(1:n)[models.range!=models.var]

## [1] 13 14 17 42 55 65 71 84 143 145 152 NA 177 179 NA NA 204 NA 211  
## [20] NA 238 NA NA NA 306 NA NA NA 345 NA NA NA NA NA 414 NA NA NA  
## [39] NA 449 NA NA NA 487 514 527 557 559 587 615

table(models.range)

## models.range  
## 1 2 3 4   
## 301 5 86 212

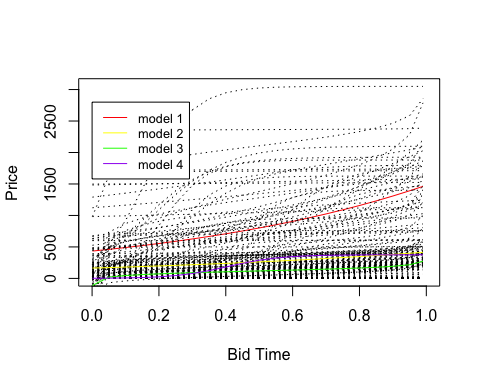
table(models.var)

## models.var  
## 1 2 3 4   
## 296 6 92 210

numauct<-length(sLive)  
x<-seq(0,duration,by=.1)  
x[1]<-min(x)+.001  
x[length(x)]<-max(x)-.01  
numplot<-length(x)  
ypred <- yfdpred7 <- ysdpred7 <- array(0,c(numauct,numplot))  
  
models<- models.range  
  
  
################################################################  
##Creating Fitted Data Based on Selected (by SSE criteria) Model  
################################################################  
## Matrix of data  
numauct<-length(sLive)  
x<-seq(0,duration,by=.05)  
x[1]<-min(x)+.001  
x[length(x)]<-max(x)-.01  
numplot<-length(x)  
ypred <- yfdpred7 <- ysdpred7 <- array(0,c(numauct,numplot))  
  
models7<- models<- models.range ###IMPT: THIS IS THE SSE CRITERIA THAT I AM USING (either models.range or models.var)   
  
for (i in 1:n){  
if (models[i]==1){  
reg1<-lm(log(sLiveEnds[[i]])~ sTimeEnds[[i]])  
ypred[i,]<-exp(as.vector(reg1$coefficients)[1])\*exp(as.vector(reg1$coefficients)[2]\*x)  
yfdpred7[i,]<-exp(as.vector(reg1$coefficients)[1])\*as.vector(reg1$coefficients)[2]\*exp(as.vector(reg1$coefficients)[2]\*x)  
ysdpred7[i,]<-exp(as.vector(reg1$coefficients)[1])\*(as.vector(reg1$coefficients)[2])^2\*exp(as.vector(reg1$coefficients)[2]\*x)  
}  
  
if (models[i]==2){  
reg2<-lm(log(sTimeEndsTemp[[i]])~ sLiveEnds[[i]])  
ypred[i,]<-log(x/exp(as.vector(reg2$coefficients)[1])) /as.vector(reg2$coefficients)[2]  
yfdpred7[i,]<-1/(as.vector(reg2$coefficients)[2]\*x)  
ysdpred7[i,]<- -1/(as.vector(reg2$coefficients)[2]\*x^2)  
}  
  
if (models[i]==3){  
reg3<- lm( log((max(sLiveStart[[i]])+delta)/sLiveStart[[i]]-1) ~ sTimeStart[[i]] )  
ypred[i,]<- (max(sLive[[i]])+delta)/(1+exp(as.vector(reg3$coefficients)[1])\*exp(as.vector(reg3$coefficients)[2]\*x))  
yfdpred7[i,]<- -(max(sLive[[i]])+delta)\*exp(as.vector(reg3$coefficients)[1])\*as.vector(reg3$coefficients)[2]\*exp(as.vector(reg3$coefficients)[2]\*x)/  
 (1+exp(as.vector(reg3$coefficients)[1])\*exp(as.vector(reg3$coefficients)[2]\*x))^2  
ysdpred7[i,]<- -(max(sLive[[i]])+delta)\*exp(as.vector(reg3$coefficients)[1])\*(as.vector(reg3$coefficients)[2])^2\*exp(as.vector(reg3$coefficients)[2]\*x)\*  
 (1-exp(as.vector(reg3$coefficients)[1])\*exp(as.vector(reg3$coefficients)[2]\*x))/  
 (1+exp(as.vector(reg3$coefficients)[1])\*exp(as.vector(reg3$coefficients)[2]\*x))^3  
}  
  
if (models[i]==4){  
reg4<- lm( log((duration+epsilon)/sTimeEndsTemp[[i]]-1) ~ sLiveEnds[[i]])  
ypred[i,]<- (log(((duration+epsilon)/x)-1) - as.vector(reg4$coefficients)[1]) /as.vector(reg4$coefficients)[2]  
yfdpred7[i,]<- -(duration+epsilon)/(as.vector(reg4$coefficients)[2]\*(x^2)\*(((duration+epsilon)/x)-1))  
ysdpred7[i,]<- ((duration+epsilon)\*((duration+epsilon)-2\*x))/(as.vector(reg4$coefficients)[2]\*(x^4)\*(((duration+epsilon)/x)-1)^2)  
}  
}

## Error in if (models[i] == 1) {: missing value where TRUE/FALSE needed

plot(x,ypred[1,],type="l",xlim=c(0,1),ylim=c(0,max(ypred)),xlab="Bid Time",ylab="Price",col='red')  
for (i in 2:numauct)  
lines(x,ypred[i,], lty=3)  
  
lines(x,ypred[86,], col='yellow')  
lines(x,ypred[61,], col='green')  
lines(x,ypred[9,], col='purple')  
  
legend(0, 2800, legend=c("model 1", "model 2", "model 3", "model 4"),  
 col=c("red", "yellow", 'green', 'purple'), lty=1, cex=0.8)



table(models)

## models  
## 1 2 3 4   
## 301 5 86 212

## Static model

library(dplyr)  
library(caret)

## Loading required package: lattice

##   
## Attaching package: 'caret'

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

# Split data into training and testing  
set.seed(123)  
Train <- createDataPartition(u, p = 0.7, list = FALSE)  
Train.auction<- auction$auctionid %in% u[Train]  
training <- auction[Train.auction,]  
testing <- auction[!Train.auction,]

## static prediction

Static competition features are known at the outset of the auction and do not change during the auction; - opening price of concurrent auctions - duration of concurrent auctions - sellers’ feedback of concurrent auctions

library(ggplot2)  
library(caret)  
  
#######Static Model Predicting the End Price######  
set.seed(123)  
train\_control<- trainControl(method = 'cv',number=10,repeats = 3)

## Warning: `repeats` has no meaning for this resampling method.

#fit auction with linear model  
static.lm <- train(price~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day, data=training, trControl=train\_control, method="lm",na.action=na.exclude)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
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## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

static.lm

## Linear Regression   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6795, 6796, 6796, 6797, 6795, 6798, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 268.2168 0.5408452 132.4348  
##   
## Tuning parameter 'intercept' was held constant at a value of TRUE

static.pred.lm<- predict(static.lm, testing)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

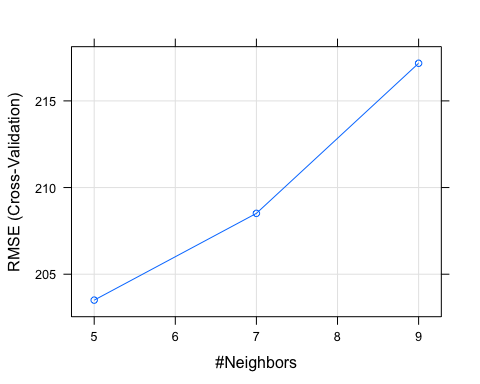
postResample(pred = static.pred.lm, obs = testing$livebid)

## RMSE Rsquared MAE   
## 303.4196504 0.3509475 184.0715687

##fit auction with knn model  
static.knn<- train(price ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day, data=training, trControl=train\_control, method="knn",na.action=na.exclude)  
static.knn

## k-Nearest Neighbors   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6797, 6796, 6796, 6795, 6795, 6796, ...   
## Resampling results across tuning parameters:  
##   
## k RMSE Rsquared MAE   
## 5 203.5048 0.7333769 76.95662  
## 7 208.5114 0.7198521 82.10603  
## 9 217.1711 0.6960207 87.56857  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was k = 5.

plot(static.knn)



static.pred.knn<- predict(static.knn, testing)  
postResample(pred = static.pred.knn, obs = testing$livebid)

## RMSE Rsquared MAE   
## 325.888647 0.268136 181.203730

library(ggplot2)  
library(caret)  
  
#######Static Model######  
set.seed(123)  
  
train\_control<- trainControl(method = 'cv',number=10,repeats = 3)

## Warning: `repeats` has no meaning for this resampling method.

#fit auction with linear model  
static.lm <- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day, data=training, trControl=train\_control, method="lm",na.action=na.exclude)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
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## may be misleading

static.lm

## Linear Regression   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6796, 6796, 6796, 6796, 6795, 6796, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 210.1425 0.4695338 112.7726  
##   
## Tuning parameter 'intercept' was held constant at a value of TRUE

static.pred.lm<- predict(static.lm, testing)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

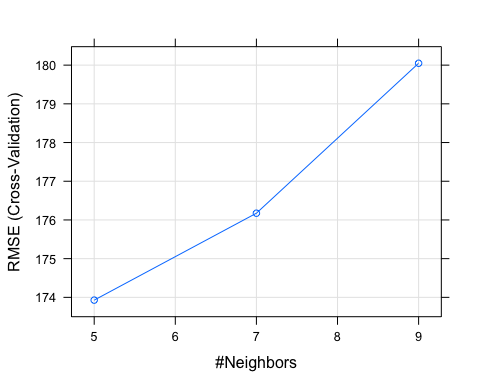
postResample(pred = static.pred.lm, obs = testing$livebid)

## RMSE Rsquared MAE   
## 232.015148 0.436801 110.296938

##fit auction with knn model  
static.knn<- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day, data=training, trControl=train\_control, method="knn",na.action=na.exclude)  
static.knn

## k-Nearest Neighbors   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6797, 6796, 6795, 6795, 6795, 6796, ...   
## Resampling results across tuning parameters:  
##   
## k RMSE Rsquared MAE   
## 5 173.9282 0.6382034 85.05969  
## 7 176.1739 0.6288147 87.21982  
## 9 180.0484 0.6126760 89.90720  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was k = 5.

plot(static.knn)



static.pred.knn<- predict(static.knn, testing)  
postResample(pred = static.pred.knn, obs = testing$livebid)

## RMSE Rsquared MAE   
## 253.5584894 0.3333473 111.1309446

#######Static + Evolving info Model######  
#current price, time left, current number of bids, current number of bidders  
  
#fit auction with linear model  
se.lm <- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day+livebid.lag+num\_current\_bids+avg.bid+sd.bid+num.bids+time.fraction, data=training, trControl=train\_control, method="lm",na.action=na.exclude)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
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## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
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## may be misleading  
  
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## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

static.lm

## Linear Regression   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6796, 6796, 6796, 6796, 6795, 6796, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 210.1425 0.4695338 112.7726  
##   
## Tuning parameter 'intercept' was held constant at a value of TRUE

se.pred.lm<- predict(se.lm, testing)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

postResample(pred = se.pred.lm, obs = testing$livebid)

## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

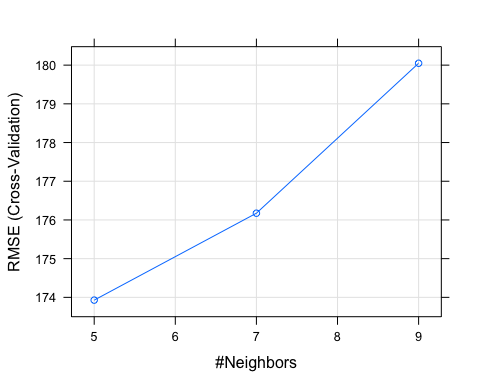
## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

## RMSE Rsquared MAE   
## 95.92843 NA 67.50273

##fit auction with knn model  
se.knn<- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day+livebid.lag+num\_current\_bids+avg.bid+sd.bid+num.bids+time.fraction, data=training, trControl=train\_control, method="knn",na.action=na.exclude)  
static.knn

## k-Nearest Neighbors   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6797, 6796, 6795, 6795, 6795, 6796, ...   
## Resampling results across tuning parameters:  
##   
## k RMSE Rsquared MAE   
## 5 173.9282 0.6382034 85.05969  
## 7 176.1739 0.6288147 87.21982  
## 9 180.0484 0.6126760 89.90720  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was k = 5.

plot(static.knn)



se.pred.knn<- predict(se.knn, testing)  
postResample(pred = se.pred.knn, obs = testing$livebid)

## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length  
  
## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

## RMSE Rsquared MAE   
## 99.06266 NA 62.78169

#######Static + Evolving info + dynamic Model######  
#distance to   
  
#fit auction with linear model  
sed.lm <- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day+livebid.lag+num\_current\_bids+avg.bid+sd.bid+num.bids+time.fraction+bid.fraction+dist.open+dist.avg+time.diff+bid.diff+velocity, data=training, trControl=train\_control, method="lm",na.action=na.exclude)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
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## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading  
  
## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

static.lm

## Linear Regression   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6796, 6796, 6796, 6796, 6795, 6796, ...   
## Resampling results:  
##   
## RMSE Rsquared MAE   
## 210.1425 0.4695338 112.7726  
##   
## Tuning parameter 'intercept' was held constant at a value of TRUE

sed.pred.lm<- predict(sed.lm, testing)

## Warning in predict.lm(modelFit, newdata): prediction from a rank-deficient fit  
## may be misleading

postResample(pred = sed.pred.lm, obs = testing$livebid)

## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

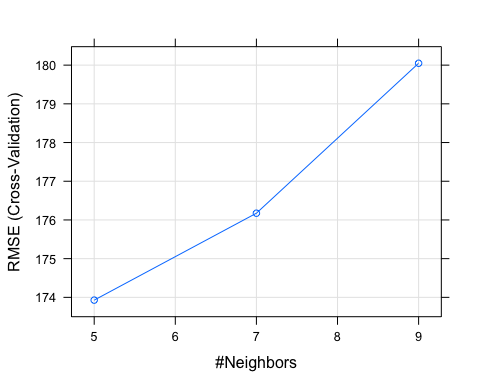
## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

## RMSE Rsquared MAE   
## 96.08527 NA 67.37456

##fit auction with knn model  
sed.knn<- train(livebid ~ openbid+length+bidderrate+is\_catier+is\_palm+is\_xbox+is\_3day+is\_5day+is\_7day+livebid.lag+num\_current\_bids+avg.bid+sd.bid+num.bids+time.fraction+bid.fraction+dist.open+dist.avg+time.diff+bid.diff+velocity, data=training, trControl=train\_control, method="knn",na.action=na.exclude)  
static.knn

## k-Nearest Neighbors   
##   
## 7562 samples  
## 9 predictor  
##   
## No pre-processing  
## Resampling: Cross-Validated (10 fold)   
## Summary of sample sizes: 6797, 6796, 6795, 6795, 6795, 6796, ...   
## Resampling results across tuning parameters:  
##   
## k RMSE Rsquared MAE   
## 5 173.9282 0.6382034 85.05969  
## 7 176.1739 0.6288147 87.21982  
## 9 180.0484 0.6126760 89.90720  
##   
## RMSE was used to select the optimal model using the smallest value.  
## The final value used for the model was k = 5.

plot(static.knn)



sed.pred.knn<- predict(sed.knn, testing)  
postResample(pred = sed.pred.knn, obs = testing$livebid)

## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length  
  
## Warning in pred - obs: longer object length is not a multiple of shorter object  
## length

## RMSE Rsquared MAE   
## 181.56717 NA 85.78306

library(ggplot2)  
library(xgboost)

##   
## Attaching package: 'xgboost'

## The following object is masked from 'package:dplyr':  
##   
## slice

library(caret)  
  
#######XGboost Full model######  
set.seed(123)  
  
train\_x<- as.matrix(training %>% select(-which(sapply(.,is.character))) %>%select(-c(livebid,auctionid)))  
  
train\_y<- training$livebid  
  
test\_x<- as.matrix(testing %>% select(-which(sapply(.,is.character))) %>%select(-c(livebid,auctionid)))  
  
test\_y<- testing$livebid  
  
full.xg<- xgboost(data = train\_x,  
 label=train\_y,  
 booster = "gblinear",  
 objective = "reg:linear",  
 max.depth = 8,  
 nround = 500,  
 lambda = 0,  
 lambda\_bias = 0,  
 alpha = 0,   
 missing=NA,   
 verbose = 0)

## Error in xgb.DMatrix(data, label = label, missing = missing): 'data' has class 'character' and length 189050.  
## 'data' accepts either a numeric matrix or a single filename.

pred.test.xgboost <- predict(full.xg,test\_x, missing=NA)

## Error in predict(full.xg, test\_x, missing = NA): object 'full.xg' not found

rmse <- function(error)  
{  
 sqrt(mean(error^2))  
}  
   
# Function that returns Mean Absolute Error  
mae <- function(error)  
{  
 mean(abs(error))  
}  
  
error<- test\_y-pred.test.xgboost

## Error in eval(expr, envir, enclos): object 'pred.test.xgboost' not found

postResample(pred = pred.test.xgboost, obs = testing$livebid)

## Error in postResample(pred = pred.test.xgboost, obs = testing$livebid): object 'pred.test.xgboost' not found

## using LSTM to predicting the bid pattern

library(keras)  
  
lags <- function(x, k){  
   
 lagged = c(rep(NA, k), x[1:(length(x)-k)])  
 DF = as.data.frame(cbind(lagged, x))  
 colnames(DF) <- c( paste0('x-', k), 'x')  
 DF[is.na(DF)] <- 0  
 return(DF)  
 }  
  
lstm.train = lags(training$bid.diff, 1)  
lstm.test = lags(testing$bid.diff, 1)  
  
  
normalize <- function(train, test, feature\_range = c(0, 1)) {  
 x = train  
 fr\_min = feature\_range[1]  
 fr\_max = feature\_range[2]  
 std\_train = ((x - min(x) ) / (max(x) - min(x) ))  
 std\_test = ((test - min(x) ) / (max(x) - min(x) ))  
   
 scaled\_train = std\_train \*(fr\_max -fr\_min) + fr\_min  
 scaled\_test = std\_test \*(fr\_max -fr\_min) + fr\_min  
   
 return( list(scaled\_train = as.vector(scaled\_train), scaled\_test = as.vector(scaled\_test) ,scaler= c(min =min(x), max = max(x))) )  
   
 }  
  
   
Scaled = normalize(train, test, c(-1, 1))

## Error in min(x): invalid 'type' (closure) of argument

y\_train = Scaled$scaled\_train[, 2]

## Error in eval(expr, envir, enclos): object 'Scaled' not found

x\_train = Scaled$scaled\_train[, 1]

## Error in eval(expr, envir, enclos): object 'Scaled' not found

y\_test = Scaled$scaled\_test[, 2]

## Error in eval(expr, envir, enclos): object 'Scaled' not found

x\_test = Scaled$scaled\_test[, 1]

## Error in eval(expr, envir, enclos): object 'Scaled' not found

dim(x\_train) <- c(length(x\_train), 1, 1)

## Error in eval(expr, envir, enclos): object 'x\_train' not found

dim(x\_train)

## Error in eval(expr, envir, enclos): object 'x\_train' not found

batch\_size = 1  
units = 1  
# specify required arguments  
model <- keras\_model\_sequential() %>%   
 layer\_lstm(units=128,batch\_input\_shape = c(batch\_size, dim(x\_train)[2], dim(x\_train)[3]), stateful= TRUE)%>%  
 layer\_dropout(0.2) %>%   
 layer\_dense(units = 1)

## Error in normalize\_shape(batch\_input\_shape): object 'x\_train' not found

model %>% compile(  
 optimizer\_adam( lr= 0.02 , decay = 1e-6 ),  
 loss = "mse",  
 metrics = list("mean\_absolute\_error")  
)

## Error in eval(lhs, parent, parent): object 'model' not found

summary(model)

## Error in summary(model): object 'model' not found

history <- model %>% fit(  
 x\_train,y\_train,  
 epochs = 10,  
 batch\_size = 1  
)

## Error in eval(lhs, parent, parent): object 'model' not found

dim(x\_test) <- c(length(x\_test), 1, 1)

## Error in eval(expr, envir, enclos): object 'x\_test' not found

yhat = model %>% predict(X, batch\_size=1)

## Error in eval(lhs, parent, parent): object 'model' not found

postResample(pred = yhat, obs = y\_test)

## Error in postResample(pred = yhat, obs = y\_test): object 'yhat' not found

evolving competition features change during the auction, such as the current price of concurrent auctions (if the price is low in other auctions, bidders may leave the focal auction) or the number of bidders in concurrent auctions (bidders may feel that their chances of winning are higher in auctions with lower competition)

price dynamic competition features capture the effect of changing dynamics in competing auctions