Bagging

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Bootstrap aggregating (bagging)

Basic idea:

1. Resample cases and recalculate predictions
2. Average or majority vote

Notes:

- Similar bias
- Reduced variance
- More useful for non-linear functions

Ozone data

```
library(ElemStatLearn); data(ozone,package="ElemStatLearn")
ozone <- ozone[order(ozone$ozone),]
head(ozone)
```

```
##     ozone radiation temperature wind
## 17      1         8          59  9.7
## 19      4        25          61  9.7
## 14      6        78          57 18.4
## 45      7        48          80 14.3
## 106     7        49          69 10.3
## 7       8        19          61 20.1
```

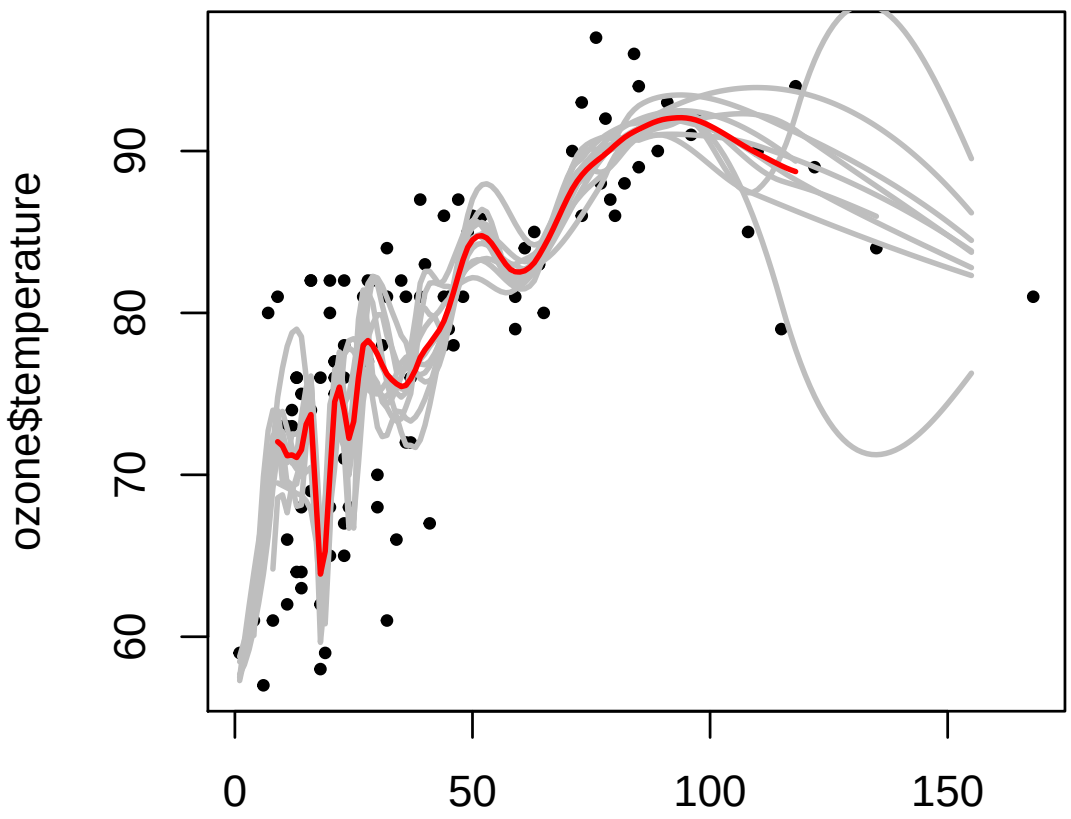
http://en.wikipedia.org/wiki/Bootstrap_aggregating

Bagged loess

```
ll <- matrix(NA,nrow=10,ncol=155)
for(i in 1:10){
  ss <- sample(1:dim(ozone)[1],replace=T)
  ozone0 <- ozone[ss,]; ozone0 <- ozone0[order(ozone0$ozone
  loess0 <- loess(temperature ~ ozone,data=ozone0,span=0.2)
  ll[i,] <- predict(loess0,newdata=data.frame(ozone=1:155))
}
```

Bagged loess

```
plot(ozone$ozone,ozone$temperature,pch=19,cex=0.5)
for(i in 1:10){lines(1:155,ll[i,],col="grey",lwd=2)}
lines(1:155,apply(ll,2,mean),col="red",lwd=2)
```



Bagging in caret

- Some models perform bagging for you, in `train` function consider `method` options
- `bagEarth`
- `treebag`
- `bagFDA`
- Alternatively you can bag any model you choose using the `bag` function

More bagging in caret

```
library(caret)
```

```
## Loading required package: lattice
```

```
## Loading required package: ggplot2
```

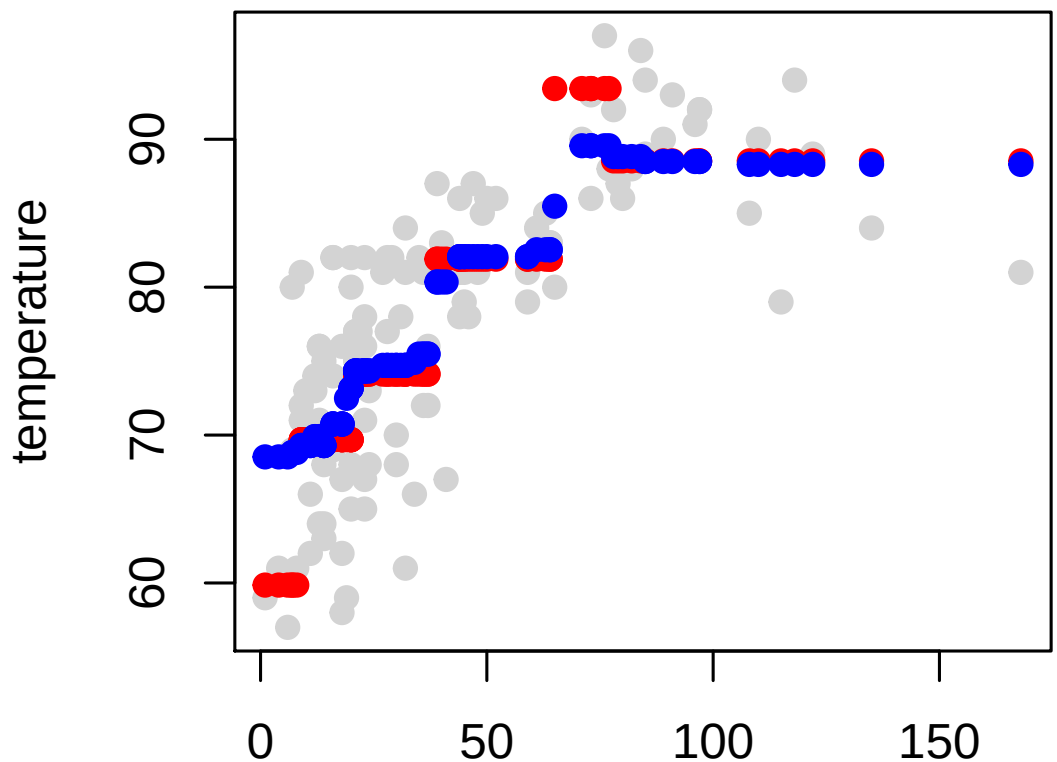
```
predictors = data.frame(ozone=ozone$ozone)
temperature = ozone$temperature
treebag <- bag(predictors, temperature, B = 10,
               bagControl = bagControl(fit = ctreeBag$fit,
                                       predict = ctreeBag$
                                       aggregate = ctreeBa
```

```
## Warning: executing %dopar% sequentially: no parallel bac
```

http://www.inside-r.org/packages/cran/caret/docs/nbBag

Example of custom bagging (continued)

```
plot(ozone$ozone,temperature,col='lightgrey',pch=19)
points(ozone$ozone,predict(treebag$fits[[1]]$fit,predictors
points(ozone$ozone,predict(treebag,predictors),pch=19,col='
```



Parts of bagging

```
ctreeBag$fit
```

```
## function (x, y, ...)
## {
##     loadNamespace("party")
##     data <- as.data.frame(x)
##     data$y <- y
##     party::ctree(y ~ ., data = data)
## }
## <environment: namespace:caret>
```

Parts of bagging

```
ctreeBag$pred
```

```
## function (object, x)
## {
##     if (!is.data.frame(x))
##         x <- as.data.frame(x)
##     obsLevels <- levels(object@data@get("response")[, 1]
##     if (!is.null(obsLevels)) {
##         rawProbs <- party::treeresponse(object, x)
##         probMatrix <- matrix(unlist(rawProbs), ncol = le
##             byrow = TRUE)
##         out <- data.frame(probMatrix)
##         colnames(out) <- obsLevels
##         rownames(out) <- NULL
##     }
##     else out <- unlist(party::treeresponse(object, x))
##     out
## }
```

Parts of bagging

```
ctreeBag$aggregate
```

```
## function (x, type = "class")
## {
##     if (is.matrix(x[[1]]) | is.data.frame(x[[1]])) {
##         pooled <- x[[1]] & NA
##         classes <- colnames(pooled)
##         for (i in 1:ncol(pooled)) {
##             tmp <- lapply(x, function(y, col) y[, col],
##             tmp <- do.call("rbind", tmp)
##             pooled[, i] <- apply(tmp, 2, median)
##         }
##         if (type == "class") {
##             out <- factor(classes[apply(pooled, 1, whic
##                 levels = classes)
##         }
##         else out <- as.data.frame(pooled)
##     }
```

Notes and further resources

Notes:

- Bagging is most useful for nonlinear models
- Often used with trees - an extension is random forests
- Several models use bagging in caret's *train* function

Further resources:

- Bagging
- Bagging and boosting
- Elements of Statistical Learning