Accumulating results: small dataframes

In this latest "R as it is" (again in collaboration with our friends at Revolution Analytics) we will quickly become expert at efficiently accumulating results in R.

A number of applications (most notably simulation) require the incremental accumulation of results prior to processing. For our example, suppose we want to collect rows of data one by one into a data frame. Take the mkRow function below as a simple example source that yields a row of data each time we call it.

Define the time sequence for the benchmarking tests

We have two options, the long and short time sequences.

```
library('microbenchmark')
library('ggplot2')

set.seed(23525) # make run more repeatable

nCol <- 10                                  # number of columns for the test DF

# If we use seq.int(10, 200, 10) we will test with dataframes of size:
#  10  20  30  40  50  60  70  80  90 100
# 110 120 130 140 150 160 170 180 190 200
timeSeq <- seq.int(10, 200, 10)             # short sequence

# If we use seq.int(100, 2000, 100) we will test with dataframes of size:
#  100  200  300  400  500  600  700  800  900 1000
# 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
timeSeq <- seq.int(100, 2000, 100)          # long sequence

summary(timeSeq)
```

```
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
    100     575    1050    1050    1525    2000 
```

Function to populate a row of data.

```
mkRow <- function(nCol) {
  x <- as.list(rnorm(nCol))
  # make row mixed types by changing first column to string
  x[[1]] <- ifelse(x[[1]]>0,'pos','neg')
  names(x) <- paste('x',seq_len(nCol),sep='.')
  x
}
```

Function for benchmarking plots of all functions

```
# build function to plot timings
# devtools::install_github("WinVector/WVPlots")
# library('WVPlots')
```

```
plotTimings <- function(timings) {
  timings$expr <- reorder(timings$expr, -timings$time, FUN=max)
  ggplot(data = timings, aes(x=nRow,y=time, color=expr)) +
    geom_point(alpha=0.8) + geom_smooth(alpha=0.8)

  nmax <- max(timings$nRow)
  tsub <- timings[timings$nRow==nmax,]
  tsub$expr <- reorder(tsub$expr,tsub$time,FUN=median)
  list(
    ggplot(data=timings,aes(x=nRow,y=time,color=expr)) +
      geom_point(alpha=0.8) + geom_smooth(alpha=0.8),
    ggplot(data=timings,aes(x=nRow,y=time,color=expr)) +
      geom_point(alpha=0.8) + geom_smooth(alpha=0.8) +
      scale_y_log10(),
    WVPlots::ScatterBoxPlot(tsub,'expr','time',
                            title=paste('nRow = ',nmax)) +
      coord_flip()
  )
}
```

1st test: mkFrameForLoop

The obvious “for-loop” solution is to collect or accumulate many rows into a data frame by repeated application of rbind. This looks like the following function.

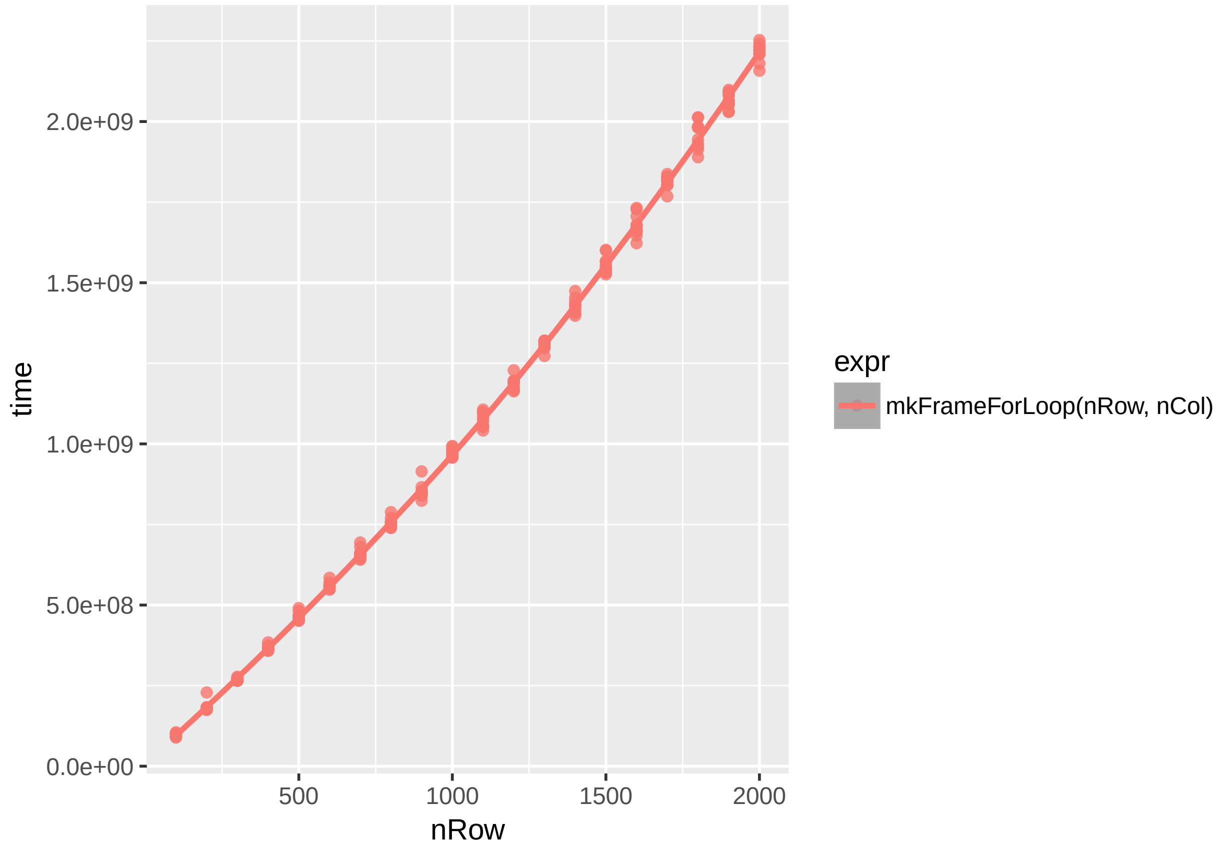
```
# The common wrong-way to accumulate the rows of data into a single data frame.
mkFrameForLoop <- function(nRow,nCol) {
  d <- c()
  for(i in seq_len(nRow)) {
    ri <- mkRow(nCol)
    di <- data.frame(ri,
                     stringsAsFactors=FALSE)
    d <- rbind(d,di)
  }
  d
}
```

Timing showing the quadratic runtime.

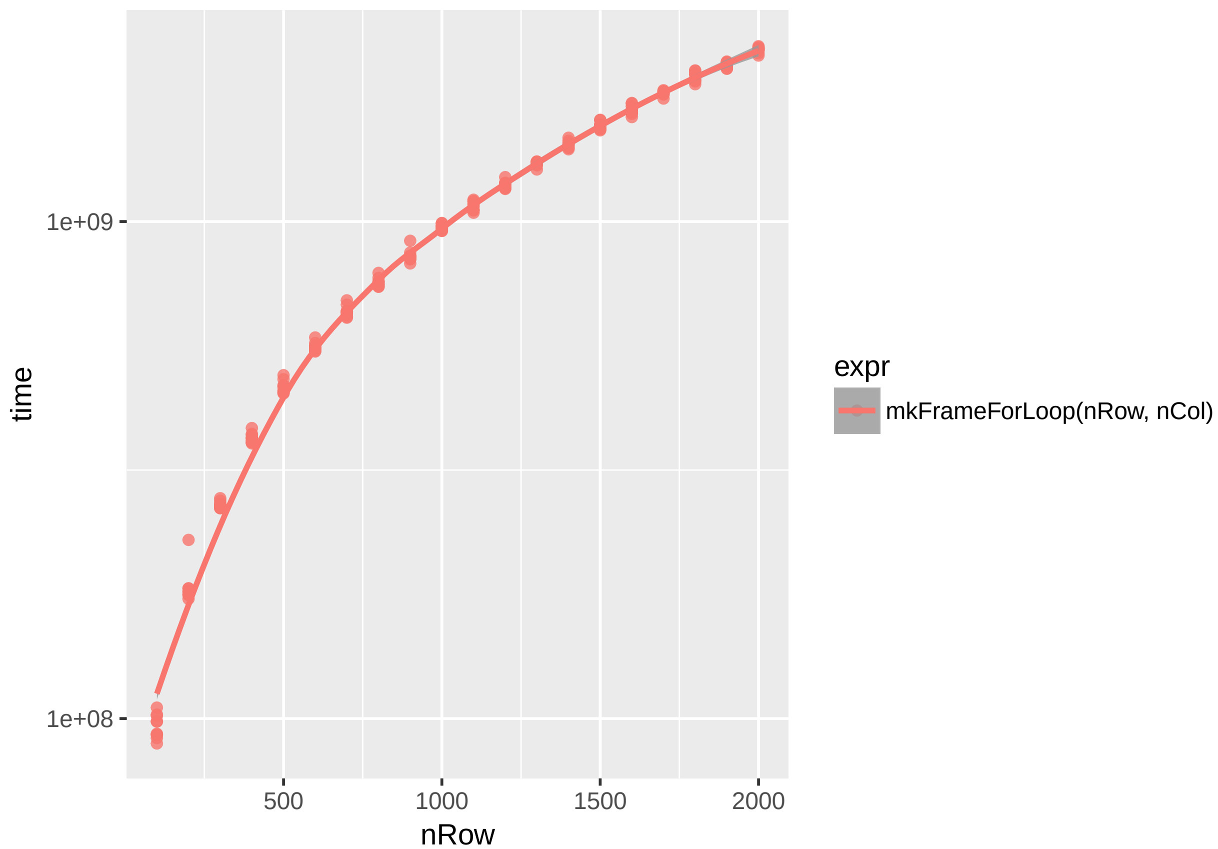
```
# this list will save the dataframes created during the test
timings <- vector("list", length(timeSeq))    # create a vector of lists

for(i in seq_len(length(timeSeq))) {      # iterate throgh time sequence
  nRow <- timeSeq[[i]]                    # get number of rows for the current DF
  ti <- microbenchmark(
    mkFrameForLoop(nRow, nCol),           # create DF
    times=10)
  ti <- data.frame(ti, stringsAsFactors = FALSE) # no factors
  ti$nRow <- nRow                         # document # rows
  ti$nCol <- nCol
  timings[[i]] <- ti                      # save DF in the list
}

timings <- data.table::rbindlist(timings) # convert DF to DT
```

```
print(plotTimings(timings))                    # plot the data
```

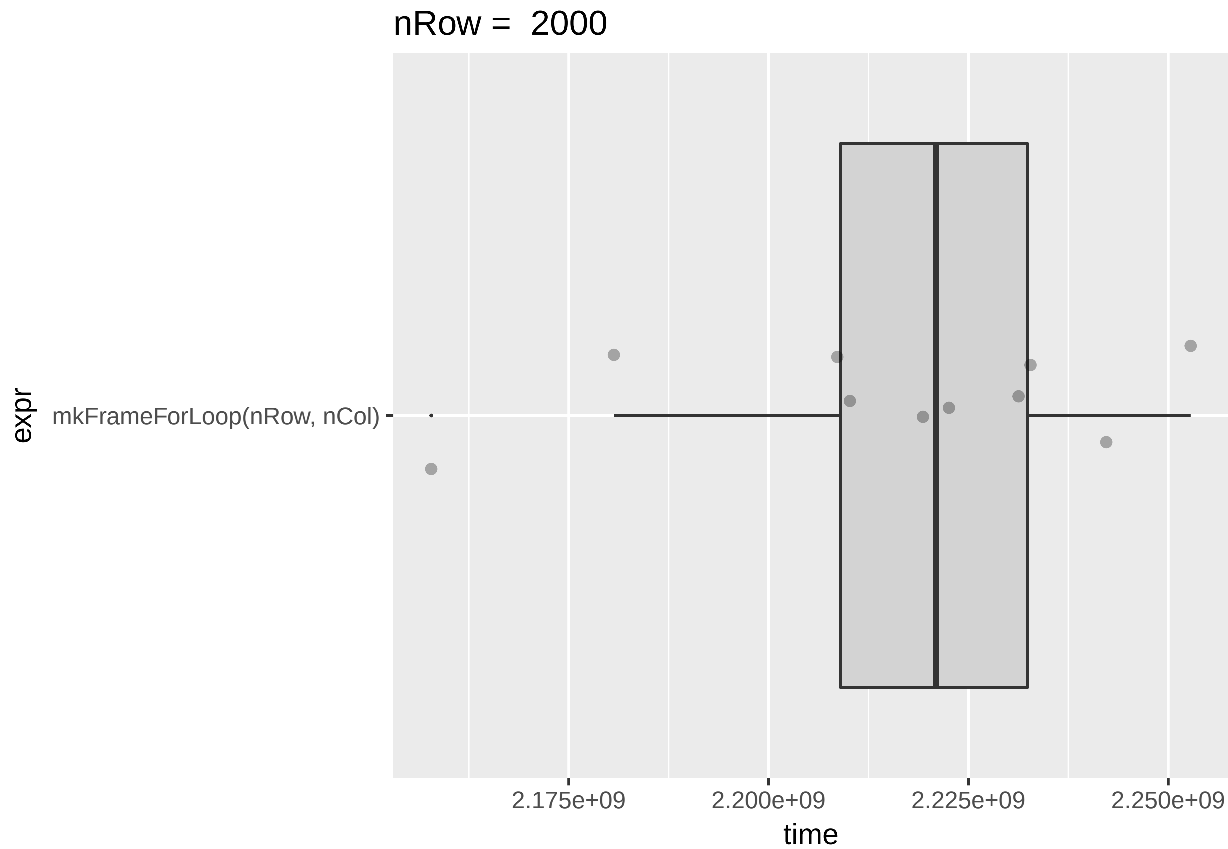
```
[[1]]
```




```
[[2]]
```


time
1e+09
1e+08
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)

```
[[3]]
```



2nd test: Benchmark mkFrameForList, mkFrameList

A few roughly equivilent right ways to accumulate the rows.

```
# Simplest fix, collect the data in a list and
# grow the list.  Exploits the fact that R can mutate
# common objects when object visibility is limited.
mkFrameForList <- function(nRow,nCol,verbose=FALSE) {
  d <- as.list(seq_len(nRow)) # pre-alloc destination
  for(i in seq_len(nRow)) {
    ri <- mkRow(nCol)
    di <- data.frame(ri,
                     stringsAsFactors=FALSE)
    d[[i]] <- di
    if(verbose) {
      print(pryr::address(d))
    }
  }
  do.call(rbind,d)
}

# Cleanest fix- wrap procedure in a function and
# use lapply.
mkFrameList <- function(nRow,nCol) {
  d <- lapply(seq_len(nRow),function(i) {
```

```r
    ri <- mkRow(nCol)
    data.frame(ri,
               stringsAsFactors=FALSE)
  })
  do.call(rbind,d)
}
```

Confirm value getting altered in place (effiency depends on interior columns also not chaning address, which is also the case).

```r
mkFrameForList(10, 5, TRUE)
```

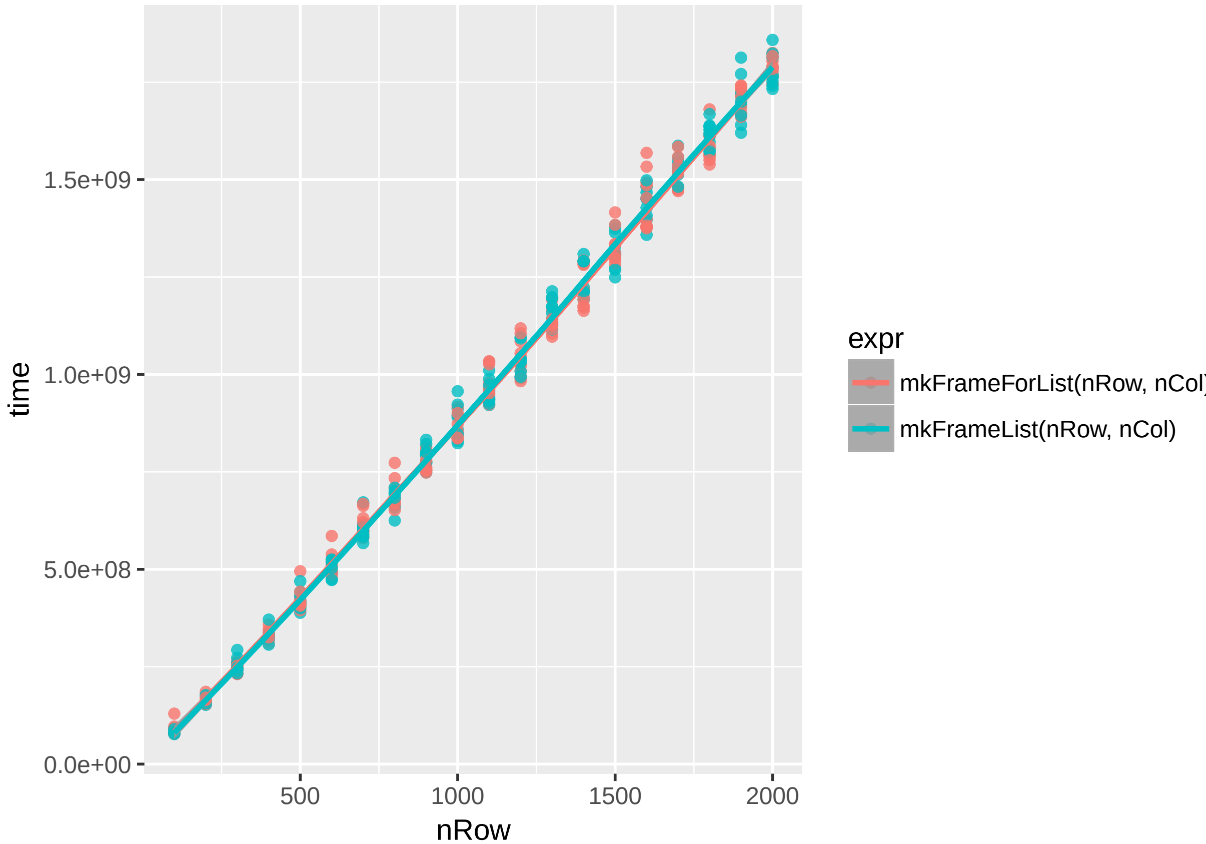
```
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
[1] "0x4d6cbe0"
```

```
   x.1        x.2          x.3          x.4        x.5
1  neg  0.6790890 -0.898065628  1.767628913  2.0261407
2  neg  1.2451843 -0.247302035  1.225230231 -0.8355865
3  pos  1.4844610 -0.135916638 -0.697913794 -0.2119939
4  neg -0.5061319  0.243461422 -2.136044488 -1.1717113
5  pos -1.5087170  0.438136858 -1.516869580 -0.2392505
6  neg  0.1381434  0.006724368 -0.134955948  0.1556312
7  neg  1.4534493 -0.455519833 -0.003664008  0.6753958
8  pos -0.9680070 -0.230603277 -1.053362288 -2.7195730
9  pos  0.1567964  1.002248329 -0.072471677 -0.2803888
10 neg -0.0498952 -0.479750792  0.891335508  0.8847961
```

Get more timings and plots for two new functions.

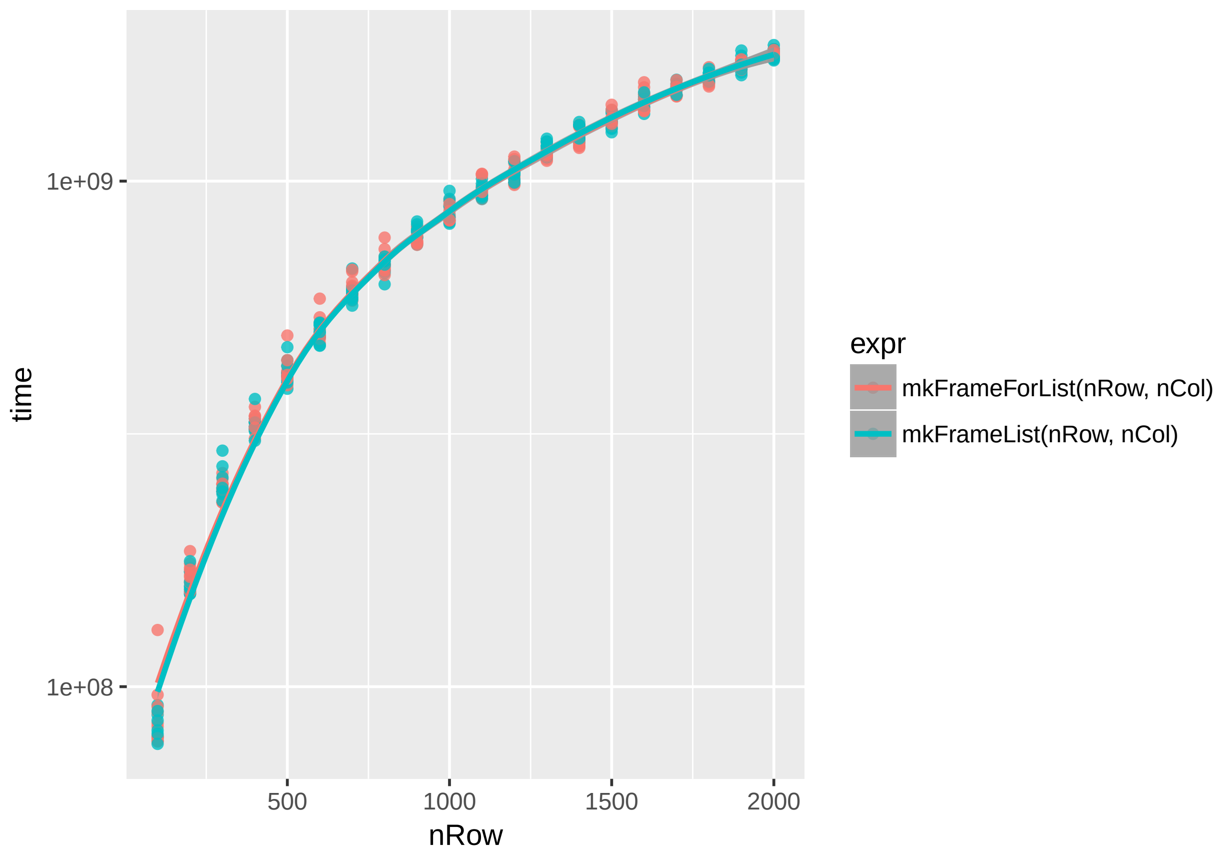
```r
timingsPrev <- timings                            # accumulate previous timings
timings <-  vector("list", length(timeSeq))

for(i in seq_len(length(timeSeq))) {
  nRow <- timeSeq[[i]]
  ti <- microbenchmark(
    mkFrameForList(nRow,nCol),
    mkFrameList(nRow,nCol),
    times=10)
  ti <- data.frame(ti,
                   stringsAsFactors=FALSE)
  ti$nRow <- nRow
  ti$nCol <- nCol
  timings[[i]] <- ti
}

timings <- data.table::rbindlist(timings)

print(plotTimings(timings))
```

[[1]]

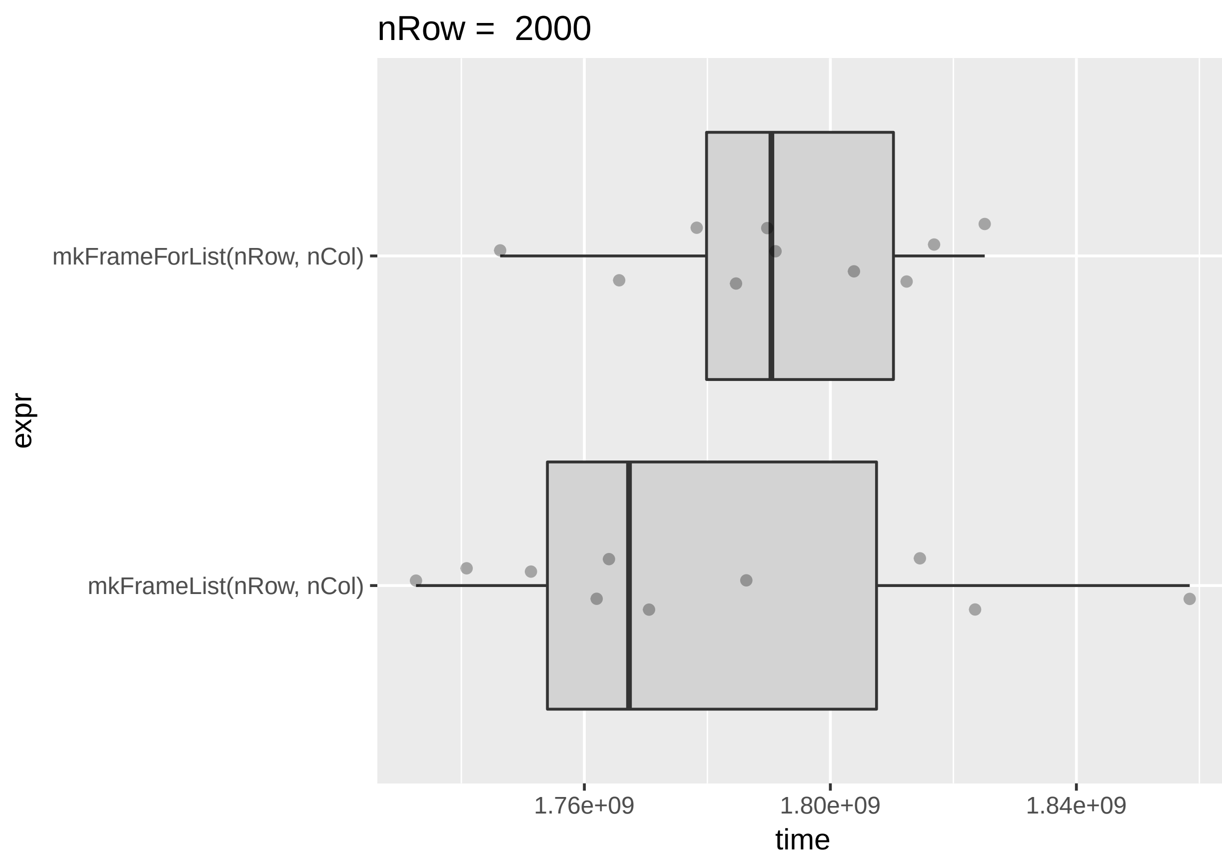


time
1.5e+09
1.0e+09
5.0e+08
0.0e+00
500
1000
1500
2000
nRow
expr
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)

[[2]]


time
1e+09
1e+08
500
1000
1500
2000
nRow
expr
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)

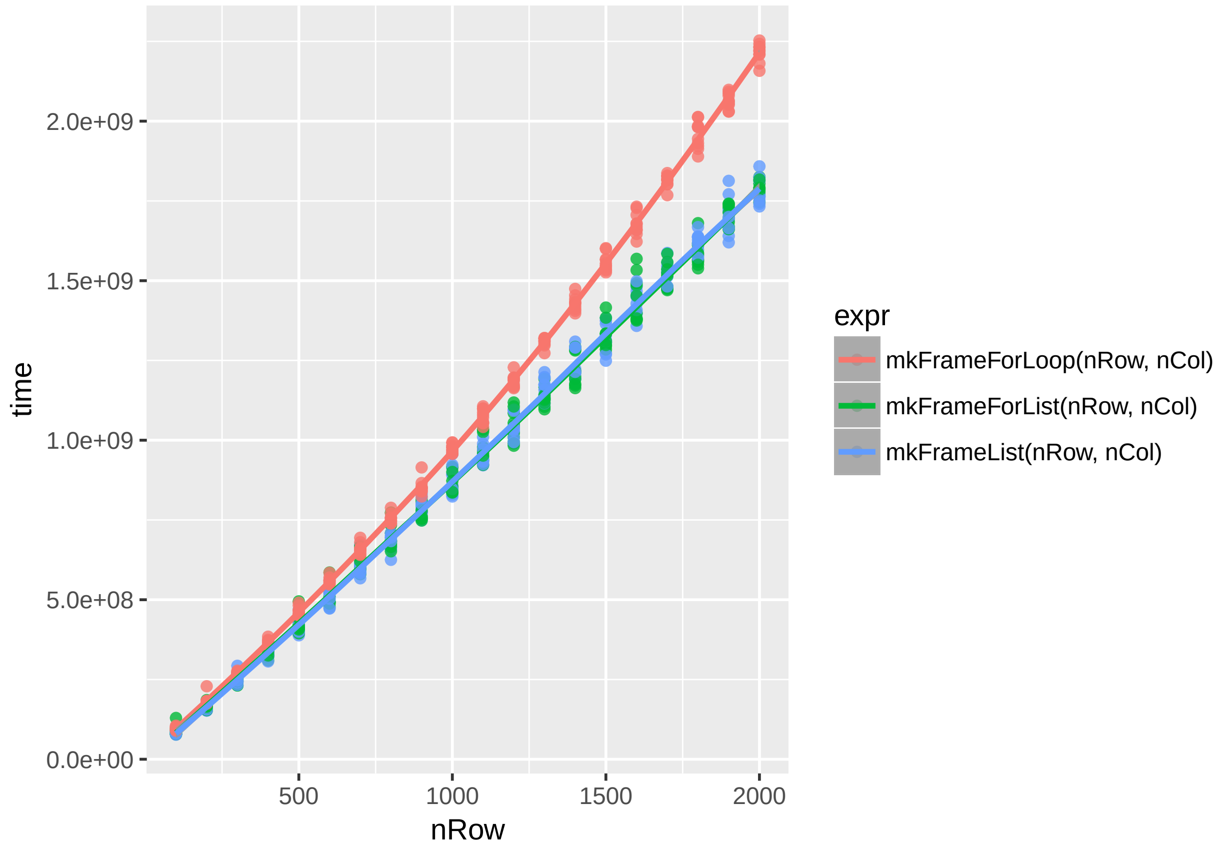
```
[[3]]
```



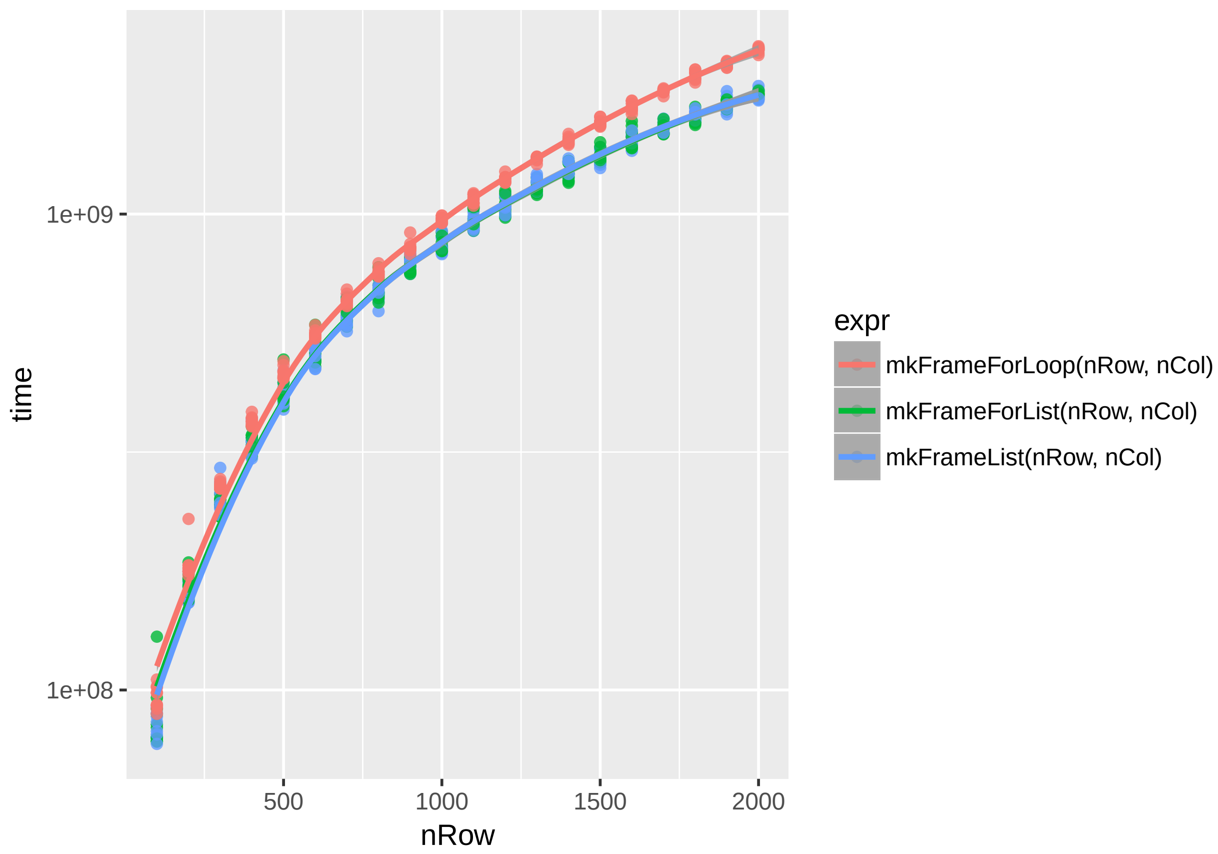
Report for previous and newer functions

```
timings <- rbind(timings, timingsPrev)

print(plotTimings(timings))
```

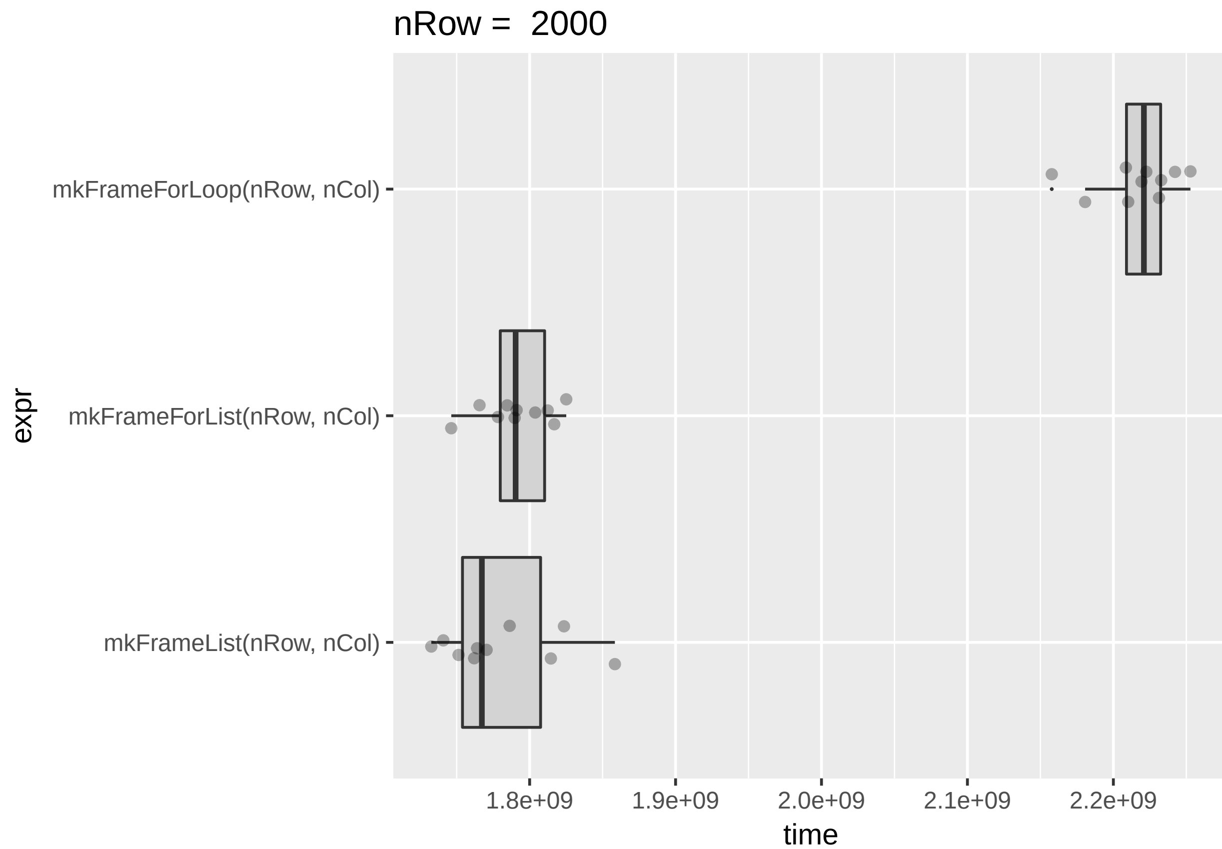
```
[[1]]
```


2.0e+09
1.5e+09
1.0e+09
5.0e+08
0.0e+00
time
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)

```
[[2]]
```

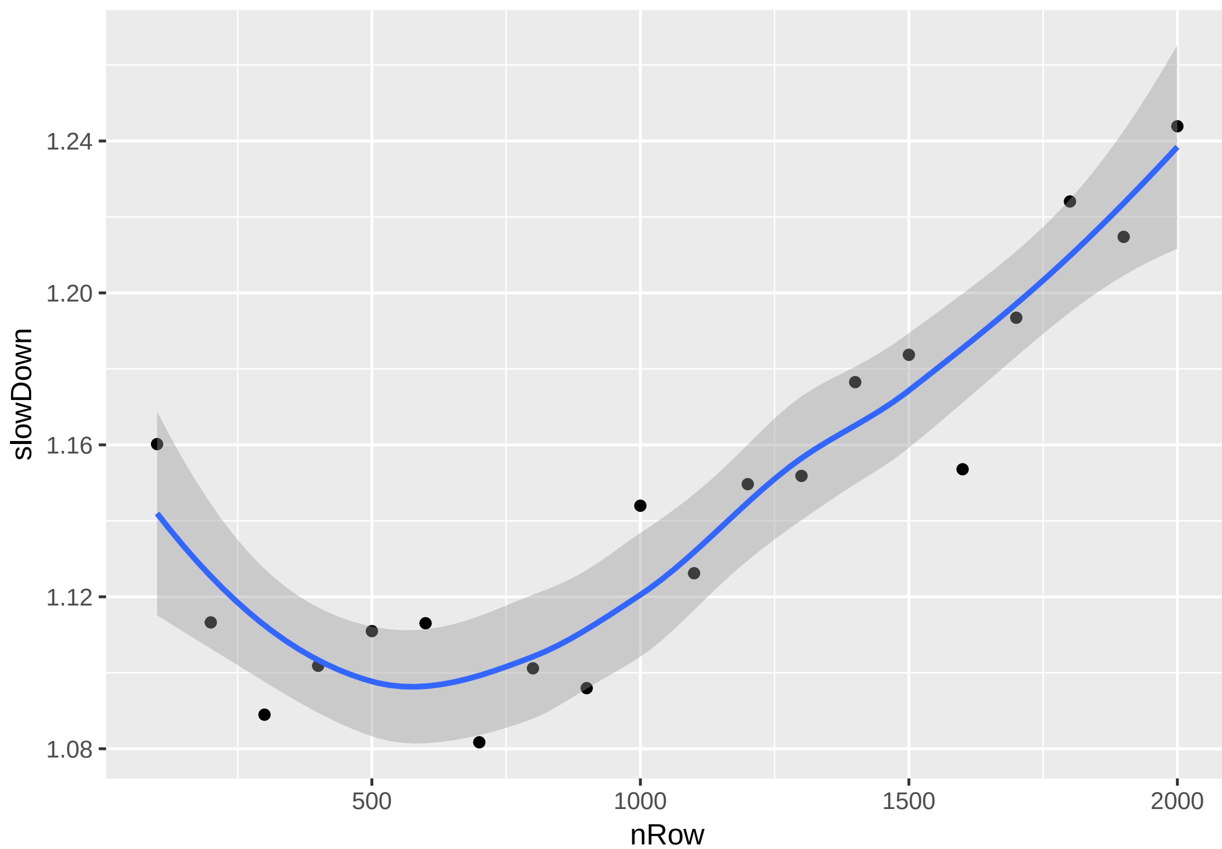

time
1e+09
1e+08
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)

```
[[3]]
```



Show slowdown of incremental method versus others as a function of number of row.

```
timingsPrev <- timings
timings$isIncremental <- timings$expr=='mkFrameForLoop(nRow, nCol)'
agg <- aggregate(time~isIncremental+nRow,data=timings,FUN=median)
dInc <- agg[agg$isIncremental,]
dInc <- dInc[order(dInc$nRow),]
dRest <- agg[!agg$isIncremental,]
dRest <- dRest[order(dRest$nRow),]
dInc$slowDown <-  dInc$time/dRest$time
ggplot(data=dInc,aes(x=nRow,y=slowDown)) +
  geom_point() + geom_smooth()
```



3rd test: mkFrameInPlace, mkFrameDataTableFor

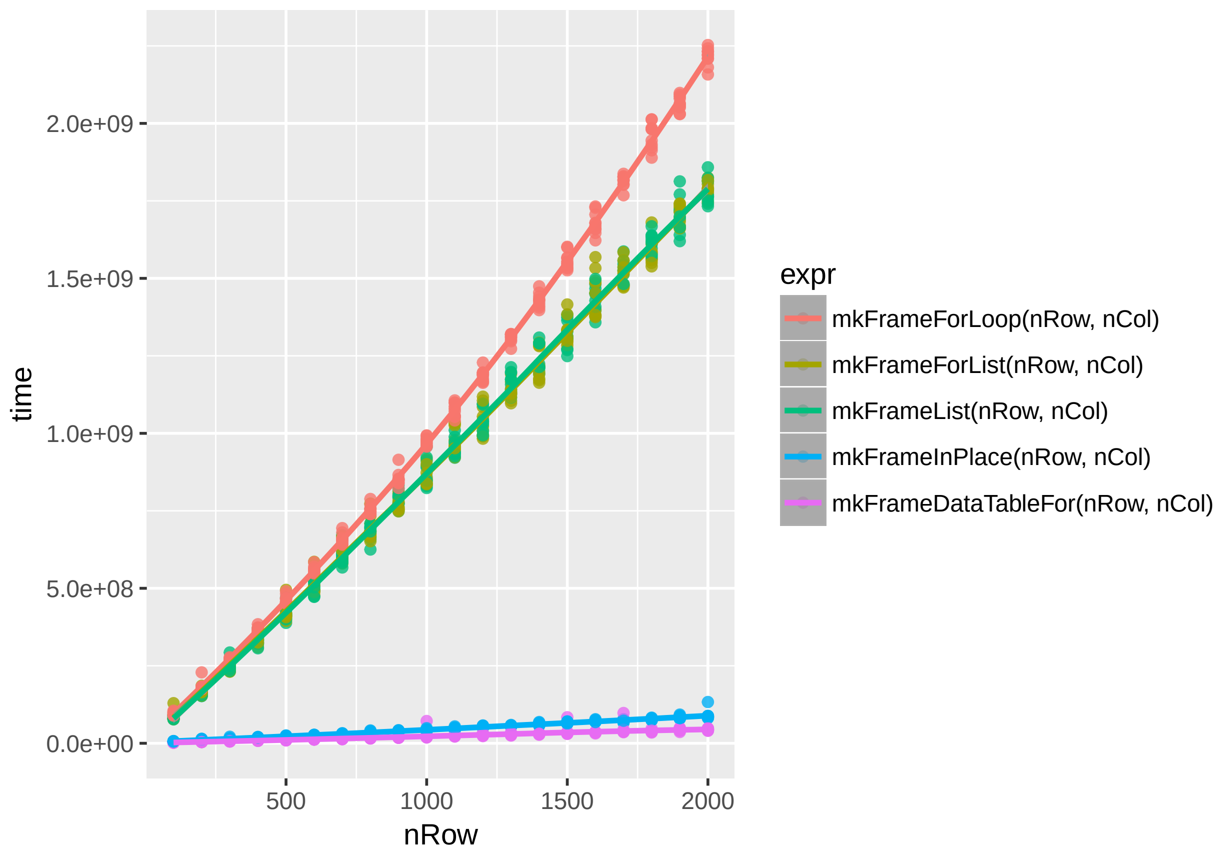
```
# From Arun Srinivasan's comment
# http://www.win-vector.com/blog/2015/07/efficient-accumulation-in-r/comment-page-1/#comment-65994
# library('data.table')
mkFrameDataTableFor <- function(nRow, nCol) {
  v = vector("list", nRow)
  for (i in seq_len(nRow)) {
    v[[i]] = mkRow(nCol)
  }
  data.table::rbindlist(v)
}

mkFrameDataTableLapply <- function(nRow, nCol) {
  v <- lapply(seq_len(nRow),function(i) {
    mkRow(nCol)
  })
  data.table::rbindlist(v)
}

# Mucking with environments fix.  Environments
# are mutable and tend to be faster than lists.
mkFrameEnvDataTable <- function(nRow,nCol) {
  e <- new.env(hash=TRUE,parent=emptyenv())
```

```r
  for(i in seq_len(nRow)) {
    ri <- mkRow(nCol)
    assign(as.character(i),ri,envir=e)
  }
  data.table::rbindlist(as.list(e))
}

# Another possibility, working in place.
mkFrameInPlace <- function(nRow,nCol,classHack=TRUE) {
  r1 <- mkRow(nCol)
  d <- data.frame(r1,
                  stringsAsFactors=FALSE)
  if(nRow>1) {
    d <- d[rep.int(1,nRow),]
    if(classHack) {
      # lose data.frame class for a while
      # changes what S3 methods implement
      # assignment.
      d <- as.list(d)
    }
    for(i in seq.int(2,nRow,1)) {
      ri <- mkRow(nCol)
      for(j in seq_len(nCol)) {
        d[[j]][[i]] <- ri[[j]]
      }
    }
  }
  if(classHack) {
     d <- data.frame(d,stringsAsFactors=FALSE)
  }
  d
}
```

Still more timings.

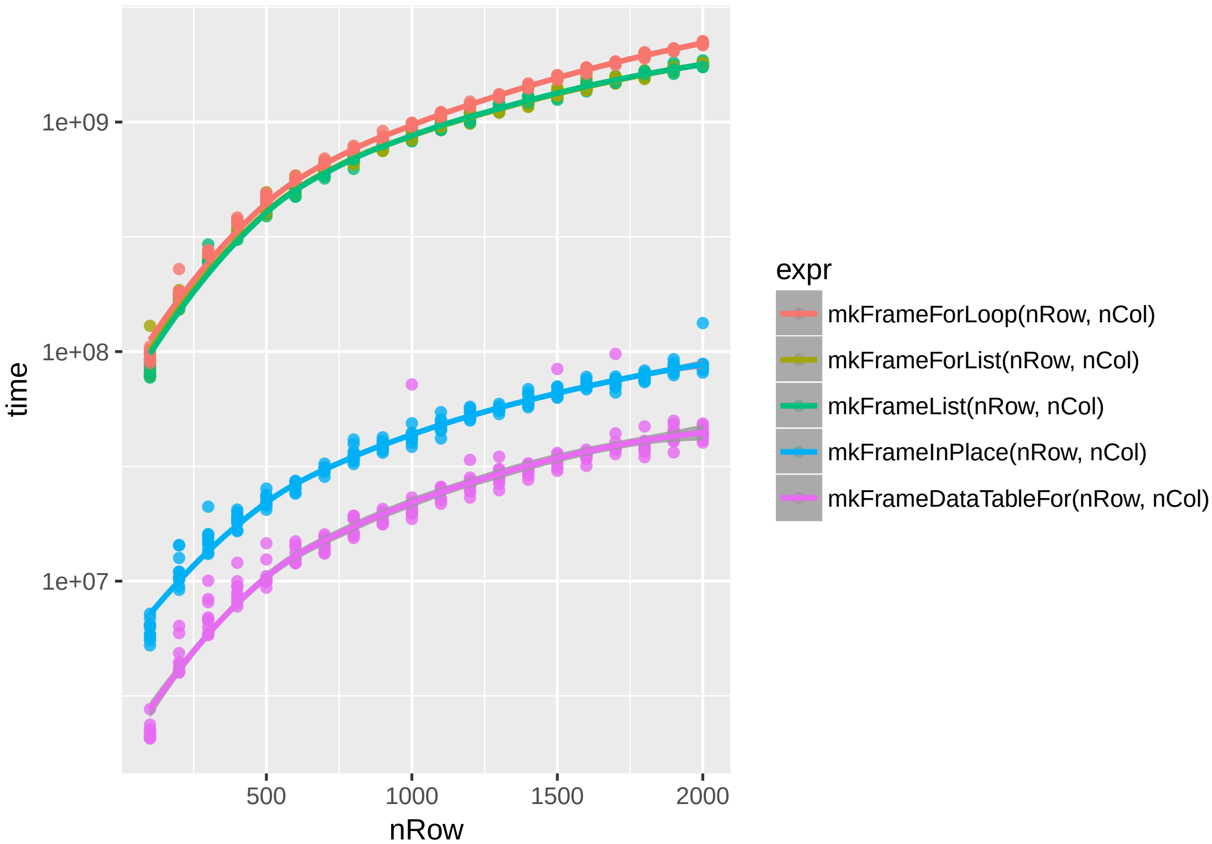
```r
timings <-  vector("list", length(timeSeq))
for(i in seq_len(length(timeSeq))) {
  nRow <- timeSeq[[i]]
  ti <- microbenchmark(
    mkFrameInPlace(nRow,nCol),
    mkFrameDataTableFor(nRow,nCol),
    times=10)
  ti <- data.frame(ti,
                   stringsAsFactors=FALSE)
  ti$nRow <- nRow
  ti$nCol <- nCol
  timings[[i]] <- ti
}
timings <- data.table::rbindlist(timings)
timings <- rbind(timings,timingsPrev)

print(plotTimings(timings))
```

```
[[1]]
```

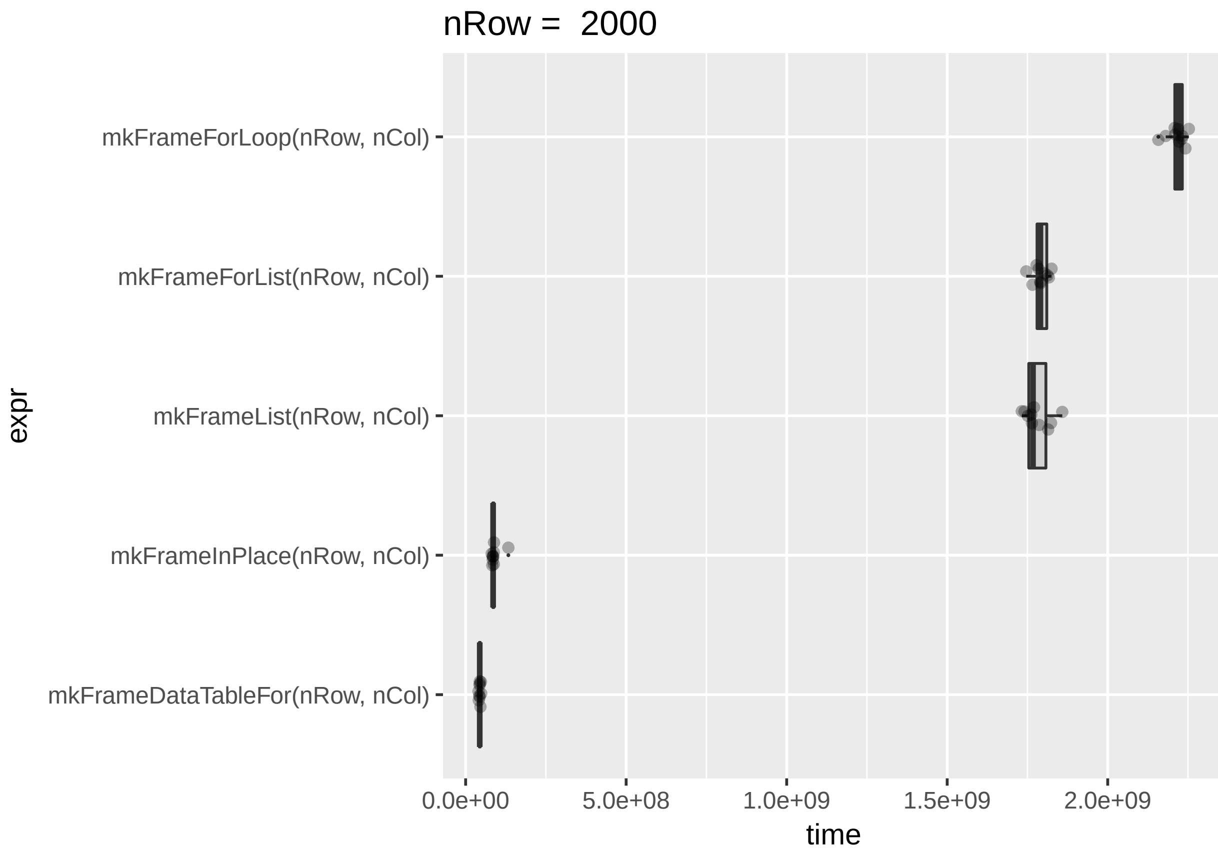


time
2.0e+09
1.5e+09
1.0e+09
5.0e+08
0.0e+00
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)
mkFrameInPlace(nRow, nCol)
mkFrameDataTableFor(nRow, nCol)


```
[[2]]
```


1e+09
1e+08
1e+07
time
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)
mkFrameInPlace(nRow, nCol)
mkFrameDataTableFor(nRow, nCol)

```
[[3]]
```



4th test: mkFrameDplyrBind, mkFramePlyrLdply, mkFrameMat, mkFrameVector, mkFrameDaccum

```
# library('dplyr')
# Fast method from https://twitter.com/drob/status/626146450842497028
mkFrameDplyrBind <- function(nRow,nCol) {
 dplyr::bind_rows(replicate(nRow,
                    data.frame(mkRow(nCol),
                               stringsAsFactors=FALSE),
                    simplify=FALSE))
}


# library('plyr')
# Idiomatic plyr https://www.reddit.com/r/rstats/comments/3ex31f/efficient_accumulation_in_r/ctjl9lq
mkFramePlyrLdply <- function(nRow,nCol) {
  plyr::ldply(seq_len(nRow),
              function(i) data.frame(mkRow(nCol),
                                     stringsAsFactors=FALSE))
}


# try to avoid all storage re-alloc, name checking, and type checking
mkFrameMat <- function(nRow,nCol) {
```

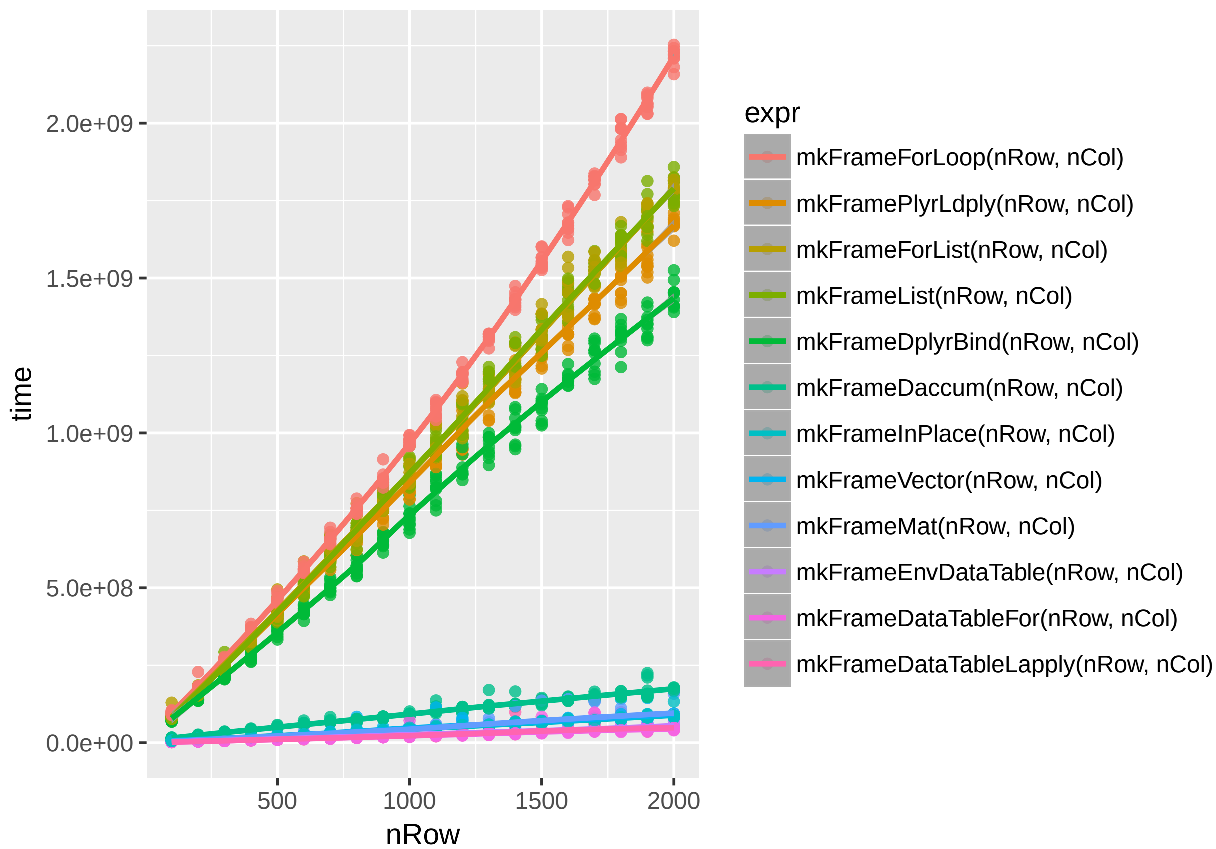
```r
  r1 <- mkRow(nCol)
  isNum <- vapply(r1,is.numeric,logical(1))
  numIndices <- seq_len(nCol)[isNum]
  strIndices <- seq_len(nCol)[!isNum]
  dN <- matrix(data="",
     nrow=nRow,ncol=length(numIndices))
  dC <- matrix(data="",
     nrow=nRow,ncol=length(strIndices))
  dN[1,] <- as.numeric(r1[numIndices])
  dC[1,] <- as.character(r1[strIndices])
  if(nRow>1) {
    for(i in seq.int(2,nRow,1)) {
      ri <- mkRow(nCol)
      dN[i,] <- as.numeric(ri[numIndices])
      dC[i,] <- as.character(ri[strIndices])
    }
  }
  dN <- data.frame(dN,stringsAsFactors=FALSE)
  names(dN) <- names(r1)[numIndices]
  dC <- data.frame(dC,stringsAsFactors=FALSE)
  names(dC) <- names(r1)[strIndices]
  cbind(dC,dN)
}


# allocate the vectors indpendently
# seems to be avoiding some overhead by not having data.frame class
# (close to current mkFrameInPlace, but faster)
# Adapted from: https://gist.github.com/jimhester/e725e1ad50a5a62f3dee#file-accumulation-r-L43-L57
mkFrameVector <- function(nRow,nCol) {
  r1 <- mkRow(nCol)
  res <- lapply(r1,function(cv) {
    if(is.numeric(cv)) {
      col = numeric(nRow)
    } else {
      col = character(nRow)
    }
    col[[1]] = cv
    col
    })
  if(nRow>1) {
    for(i in seq.int(2,nRow,1)) {
      ri <- mkRow(nCol)
      for(j in seq_len(nCol)) {
        res[[j]][[i]] <- ri[[j]]
      }
    }
  }
  data.frame(res,stringsAsFactors=FALSE)
}

# Efficient method that doesn't need to know how many rows are coming
# devtools::install_github("WinVector/daccum")
```

```r
# library('daccum')
mkFrameDaccum <- function(nRow,nCol) {
  collector <- daccum::mkColletor()
  for(i in seq_len(nRow)) {
    ri <- mkRow(nCol)
    daccum::collectRows(collector,ri)
  }
  daccum::unwrapRows(collector)
}
```

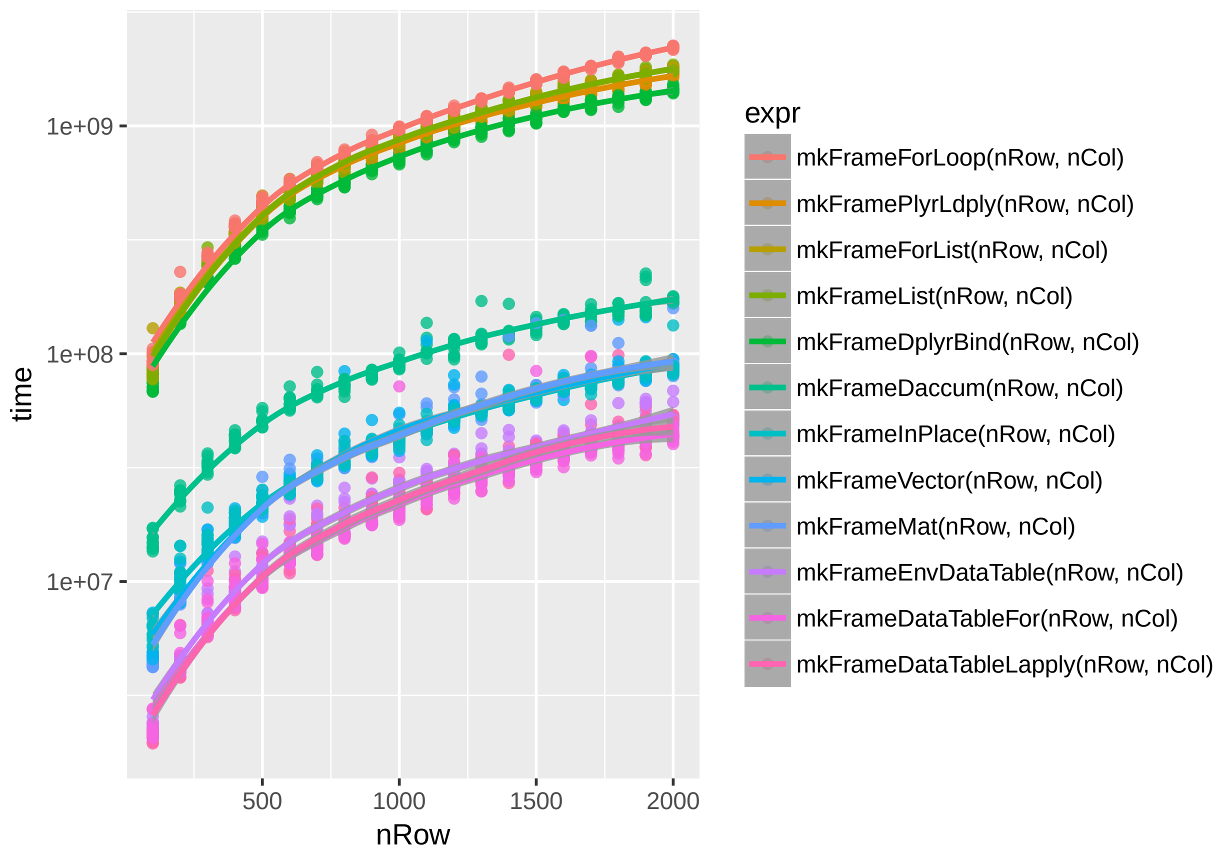
Final comparison

```r
timingsPrev <- timings
timings <-  vector("list", length(timeSeq))

for(i in seq_len(length(timeSeq))) {
  nRow <- timeSeq[[i]]
  ti <- microbenchmark(
    mkFrameDplyrBind(nRow, nCol),
    mkFramePlyrLdply(nRow, nCol),
    mkFrameMat(nRow, nCol),
    mkFrameVector(nRow, nCol),
    mkFrameDaccum(nRow, nCol),
    mkFrameEnvDataTable(nRow, nCol),
    mkFrameDataTableLapply(nRow, nCol),
    times = 10)                                  # benchmark 10 times

  ti <- data.frame(ti, stringsAsFactors=FALSE)   # create DF with timings
  ti$nRow <- nRow                                # document # rows
  ti$nCol <- nCol                                # document # columns
  timings[[i]] <- ti                             # add DF to the list `timings`
}

timings <- data.table::rbindlist(timings, fill = TRUE)
timings <- rbind(timings, timingsPrev)

print(plotTimings(timings))
```

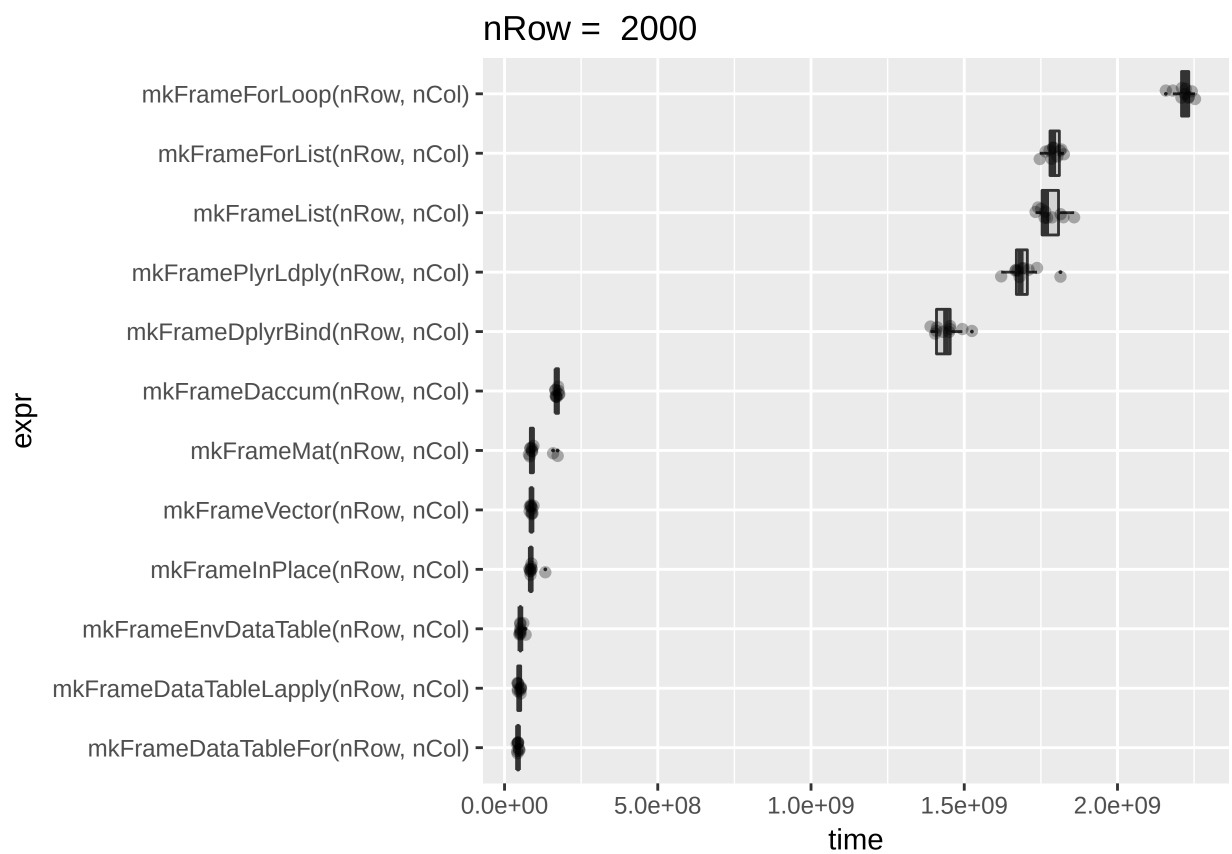
```
[[1]]
```


expr
mkFrameForLoop(nRow, nCol)
mkFramePlyrLdply(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)
mkFrameDplyrBind(nRow, nCol)
mkFrameDaccum(nRow, nCol)
mkFrameInPlace(nRow, nCol)
mkFrameVector(nRow, nCol)
mkFrameMat(nRow, nCol)
mkFrameEnvDataTable(nRow, nCol)
mkFrameDataTableFor(nRow, nCol)
mkFrameDataTableLapply(nRow, nCol)
time
2.0e+09
1.5e+09
1.0e+09
5.0e+08
0.0e+00
500
1000
1500
2000
nRow

```
[[2]]
```


1e+09
1e+08
1e+07
time
500
1000
1500
2000
nRow
expr
mkFrameForLoop(nRow, nCol)
mkFramePlyrLdply(nRow, nCol)
mkFrameForList(nRow, nCol)
mkFrameList(nRow, nCol)
mkFrameDplyrBind(nRow, nCol)
mkFrameDaccum(nRow, nCol)
mkFrameInPlace(nRow, nCol)
mkFrameVector(nRow, nCol)
mkFrameMat(nRow, nCol)
mkFrameEnvDataTable(nRow, nCol)
mkFrameDataTableFor(nRow, nCol)
mkFrameDataTableLapply(nRow, nCol)

```
[[3]]
```



Miscelaneous

Show the in-place alteration of objects in a simpler setting.

```
computeSquares <- function(n,
                           messUpVisibility,
                           usePRYR=FALSE) {
  # pre-allocate v
  # (doesn't actually help!)
  v <- 1:n
  if(messUpVisibility) {
     vLast <- v
  }
  # print details of v
  .Internal(inspect(v))
  if(usePRYR) {
    print(pryr::address(v))
  }
  for(i in 1:n) {
    v[[i]] <- i^2
    if(messUpVisibility) {
      vLast <- v
    }
    # print details of v
    .Internal(inspect(v))
```

```
    if(usePRYR) {
      print(pryr::address(v))
    }
  }
  v
}
```

Show how if the value associated with v is visible only to the variable name "v" that R will start performing in-place replacement (making calculation much cheaper).

```
computeSquares(5, FALSE)
```

```
@0x0000000004922650 13 INTSXP g0c3 [NAM(1)] (len=5, tl=0) 1,2,3,4,5
@0x000000000618b160 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,2,3,4,5
@0x000000000618b160 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,3,4,5
@0x000000000618b160 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,4,5
@0x000000000618b160 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,16,5
@0x000000000618b160 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,16,25
```

```
[1]  1  4  9 16 25
```

Show how if the value associated with v is visible to more than one variable that R will not performing in-place replacement (making calcultion much more expensive).

```
computeSquares(5, TRUE)
```

```
@0x00000000063a7f70 13 INTSXP g0c3 [NAM(2)] (len=5, tl=0) 1,2,3,4,5
@0x000000000600d1f8 14 REALSXP g0c4 [NAM(2)] (len=5, tl=0) 1,2,3,4,5
@0x000000000600d190 14 REALSXP g0c4 [NAM(2)] (len=5, tl=0) 1,4,3,4,5
@0x000000000600d128 14 REALSXP g0c4 [NAM(2)] (len=5, tl=0) 1,4,9,4,5
@0x000000000600d0c0 14 REALSXP g0c4 [NAM(2)] (len=5, tl=0) 1,4,9,16,5
@0x000000000600cff0 14 REALSXP g0c4 [NAM(2)] (len=5, tl=0) 1,4,9,16,25
```

```
[1]  1  4  9 16 25
```

Check if we can use PRYR for addresses in this case.

```
computeSquares(5, FALSE, usePRYR=TRUE)
```

```
@0x0000000008584178 13 INTSXP g0c3 [NAM(1)] (len=5, tl=0) 1,2,3,4,5
[1] "0x8584178"
@0x00000000054a7000 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,2,3,4,5
[1] "0x54a7000"
@0x00000000054a7000 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,3,4,5
[1] "0x54a7000"
@0x00000000054a7000 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,4,5
[1] "0x54a7000"
@0x00000000054a7000 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,16,5
[1] "0x54a7000"
@0x00000000054a7000 14 REALSXP g0c4 [NAM(1)] (len=5, tl=0) 1,4,9,16,25
[1] "0x54a7000"
```

```
[1]  1  4  9 16 25
```