One hour tutorial

data.table

R/Finance Chicago, May 2014

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Overview

- data.table in a nutshell (10 mins)
- Q & A. Our backgrounds (10 mins)
- Main features in more detail (30 mins)
- Q & A (10 mins)

Every question is a good question!

- Please complete feedback form at the end of the conference

What is data.table?

- Think `data.frame`, inherits from it
- `data.table()` and `?data.table`

Goals:

- Reduce programming time

  fewer function calls, less variable name repetition
- Reduce compute time

  fast aggregation, update by reference
- In-memory only, 64bit and 8GB+ routine
- Useful in finance but wider use in mind, too

  e.g. genomics

Reducing programming time

```
trades[
   filledShares < orderedShares,
   sum( (orderedShares-filledShares)
          * orderPrice / fx ),
   by = "date,region,algo"
]
```

```
R   :   i        j          by
SQL :   WHERE    SELECT     GROUP BY
```

Reducing compute time

e.g. 10 million rows x 3 columns x,y,v   230MB

```
DF[DF$x=="R" & DF$y==123,]     # 8     s
DT[.("R",123)]                 # 0.008s

tapply(DF$v,DF$x,sum)          # 22    s
DT[,sum(v),by=x]               #  0.83s
```

See above in timings vignette (copy and paste)

Fast and friendly file reading

e.g. 50MB .csv, 1 million rows x 6 columns

```
read.csv("test.csv")                # 30-60s

read.csv("test.csv", colClasses=,
             nrows=, etc...)        #    10s

fread("test.csv")                   #     3s
```

e.g. 20GB .csv, 200 million rows x 16 columns

```
read.csv("big.csv", ...)            #  hours

fread("big.csv")                    #     8m
```

Update by reference using `:=`

Add new column ”sectorMCAP” by group :

```
DT[,sectorMCAP:=sum(MCAP),by=Sector]
```

Delete a column (0.00s even on 20GB table) :

```
DT[,colToDelete:=NULL]
```

Be explicit to really copy entire 20GB :

```
DT2 = copy(DT)
```

Why R?

1) R's lazy evaluation enables the syntax :
   - `DT[ filledShares < orderedShares ]`
   - query optimization before evaluation
2) Pass `DT` to any package taking `DF`. It works.

   `is.data.frame(DT) == TRUE`
3) CRAN (cross platform release, quality control)
4) Thousands of statistical packages to use with data.table

Q & A

- My background

- Your background; e.g.
  - Bank, asset management, other?
  - Research, trading, risk, all, other?
  - Equity, futures, other?
  - Low frequency, high frequency?
  - How long using R, SQL, data.table?
  - Question?

Essential!

- Given a 10,000 x 10,000 matrix in any language
- Sum the rows
- Sum the columns
- Is one way faster, and <u>why</u>?

setkey(DT, colA, colB)

- Sorts the table by colA then colB. That's all.
- Like a telephone number directory: last name then first name
- X[Y] is just binary search to X's key
- You **DO** need a key for joins X[Y]
- You **DO NOT** need a key for by= (but many examples online include it)

Joins: X[Y]

- Vector search vs binary search
- One column == is ok, but not 2+ (see example above)
- J(), .(), list(), data.table()
- CJ()
- SJ()
- nomatch
- mult

”Cold” by (i.e. without setkey)

Consecutive calls unrelated to key are fine and common practice :

```
> DT[, sum(v), by="x,y"]
> DT[, sum(v), by="z"]
> DT[, sum(v), by=colA%%5]
```

Also known as "ad hoc by"

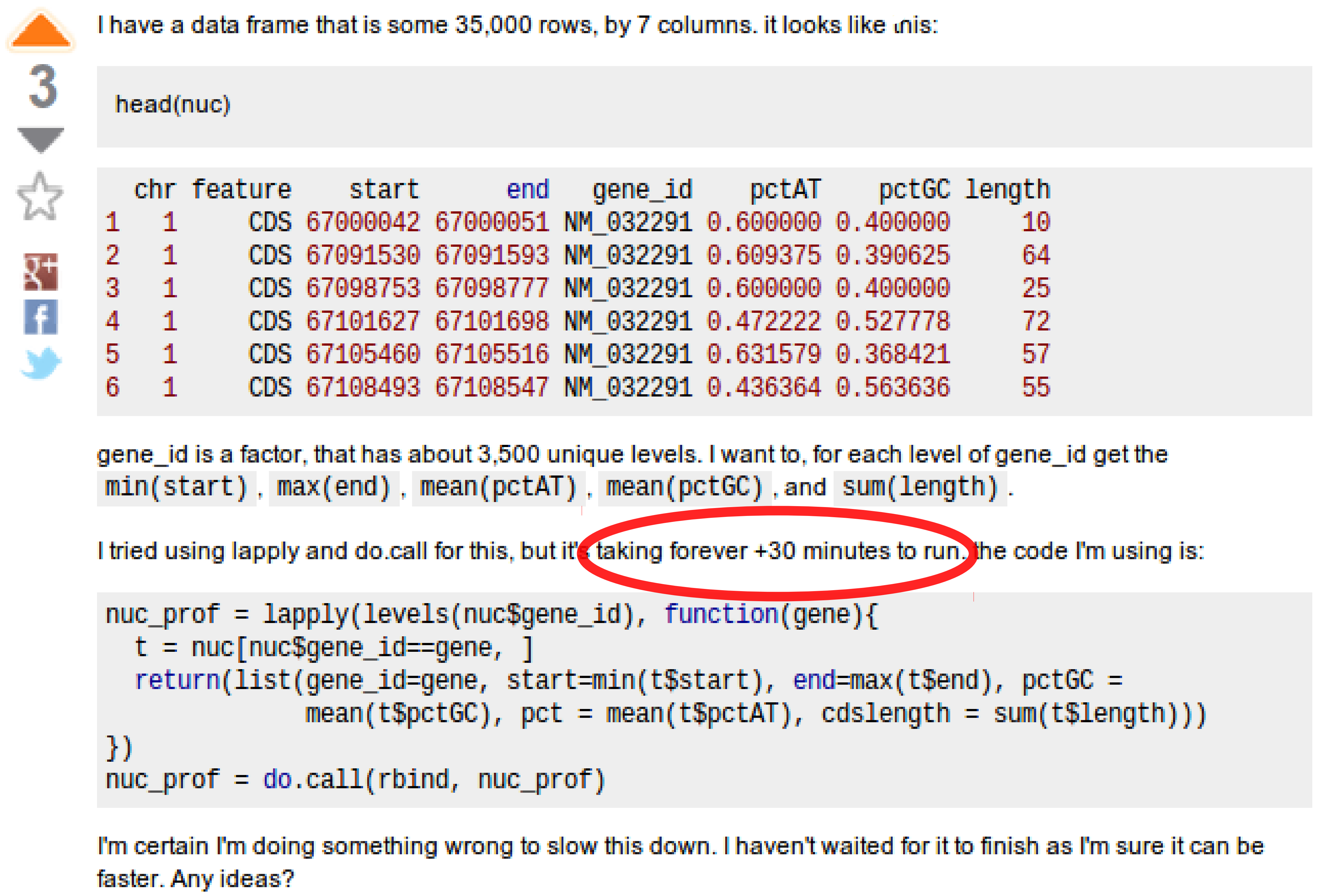
DT[i, j, by]

- Out loud: ”Take **`DT`**, subset rows using **`i`**, then calculate **`j`** grouped by **`by`**”

- Once you grok the above reading, you don't need to memorize any other functions as all operations follow the same intuition as base.

lapply and do.call running very slowly?

June 2012



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I have a data frame that is some 35,000 rows, by 7 columns. it looks like this:

```
head(nuc)
```

```
  chr feature     start       end   gene_id    pctAT    pctGC length
1   1     CDS 67000042 67000051 NM_032291 0.600000 0.400000     10
2   1     CDS 67091530 67091593 NM_032291 0.609375 0.390625     64
3   1     CDS 67098753 67098777 NM_032291 0.600000 0.400000     25
4   1     CDS 67101627 67101698 NM_032291 0.472222 0.527778     72
5   1     CDS 67105460 67105516 NM_032291 0.631579 0.368421     57
6   1     CDS 67108493 67108547 NM_032291 0.436364 0.563636     55
```

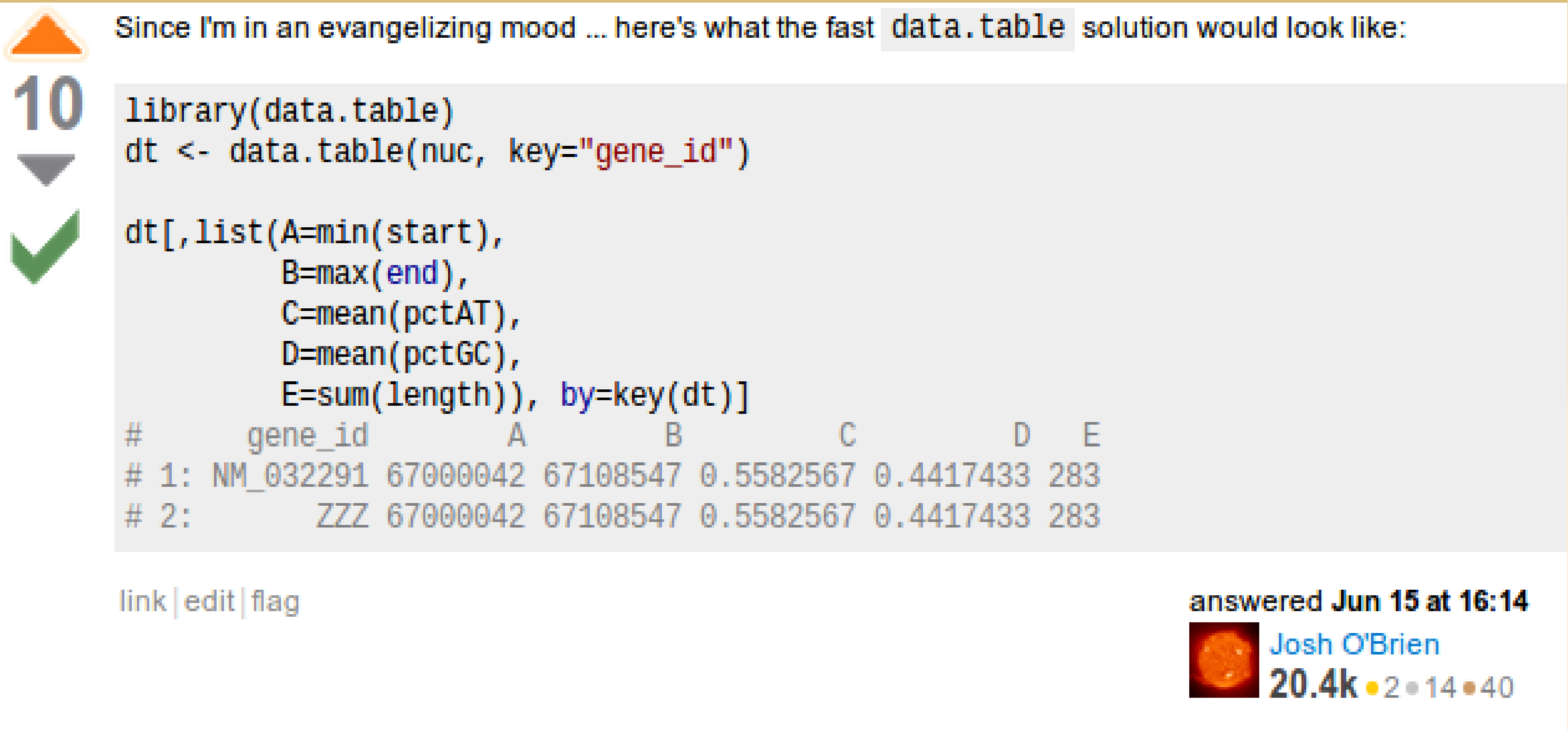
gene_id is a factor, that has about 3,500 unique levels. I want to, for each level of gene_id get the `min(start)`, `max(end)`, `mean(pctAT)`, `mean(pctGC)`, and `sum(length)`.

I tried using lapply and do.call for this, but it's taking forever +30 minutes to run. the code I'm using is:

```
nuc_prof = lapply(levels(nuc$gene_id), function(gene){
  t = nuc[nuc$gene_id==gene, ]
  return(list(gene_id=gene, start=min(t$start), end=max(t$end), pctGC =
                mean(t$pctGC), pct = mean(t$pctAT), cdslength = sum(t$length)))
})
nuc_prof = do.call(rbind, nuc_prof)
```

I'm certain I'm doing something wrong to slow this down. I haven't waited for it to finish as I'm sure it can be faster. Any ideas?

data.table answer



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Since I'm in an evangelizing mood ... here's what the fast `data.table` solution would look like:

```
library(data.table)
dt <- data.table(nuc, key="gene_id")

dt[,list(A=min(start),
         B=max(end),
         C=mean(pctAT),
         D=mean(pctGC),
         E=sum(length)), by=key(dt)]
#       gene_id        A        B         C         D   E
# 1: NM_032291 67000042 67108547 0.5582567 0.4417433 283
# 2:       ZZZ 67000042 67108547 0.5582567 0.4417433 283
```

link | edit | flag

answered **Jun 15 at 16:14**

Josh O'Brien
20.4k ●2 ●14 ●40

NB: It isn't just the speed, but the simplicity. It's easy to write and easy to read.

User's reaction

”Holy fudge buckets!!! data.table is awesome! That took about 3 seconds for the whole thing!!!”

”I think that congratulations are well in order for the frankly amazingly well written quick start guide and FAQ. Seriously.”

Davy Kavanagh, 15 Jun 2012

but ...

- Example had **`by=key(dt)`** ?

- Yes, but it didn't need to.

- If the data is very large (1GB+) and the groups are big too then getting the groups together in memory can speed up a bit (cache efficiency).

DT[,,by=] -vs- DT[,,keyby=]

- **`by`** preserves order of groups (by order of first appearance)
- Both preserve order of rows within groups (important!) and unlike SQL
- **`keyby`** is a **`by`** as usual, followed by **`setkeyv(DT,by)`**

Prevailing join (roll=TRUE)

- One reason for setkey's design.
- Last Observation (the prevailing one) Carried Forward (LOCF), efficiently
- Roll forwards or backward
- Roll the last observation forwards, or not
- Roll the first observation backwards, or not
- Limit the roll; e.g. 30 days (roll = 30)
- Join to nearest value (roll = ”nearest”)
- i.e. ***ordered joins***

Variable name repetition

- The 3rd highest voted [R] question (of 43k)

  How to sort a dataframe by column(s) in R (*)
- DF[with(DF, order(-z, b)),]
  - vs -
  DT[order(-z, b)]
- quarterlyreport[with(lastquarterlyreport,order(-z,b)),]
  - vs -
  quarterlyreport[order(-z, b)]

  Silent incorrect results due to using a similar variable by mistake. Easily done when this appears on a page of code.

(*) Click link for more information

but ...

- Yes order() is slow when used in i because that's base R's order().
- That's where ”optimization before evaluation” comes in. We now auto convert order() to the internal forder() so you don't have to know.
- Available in v1.9.3 on R-Forge, soon on CRAN

split-apply-combine

Why ”split” 10GB into many small groups???

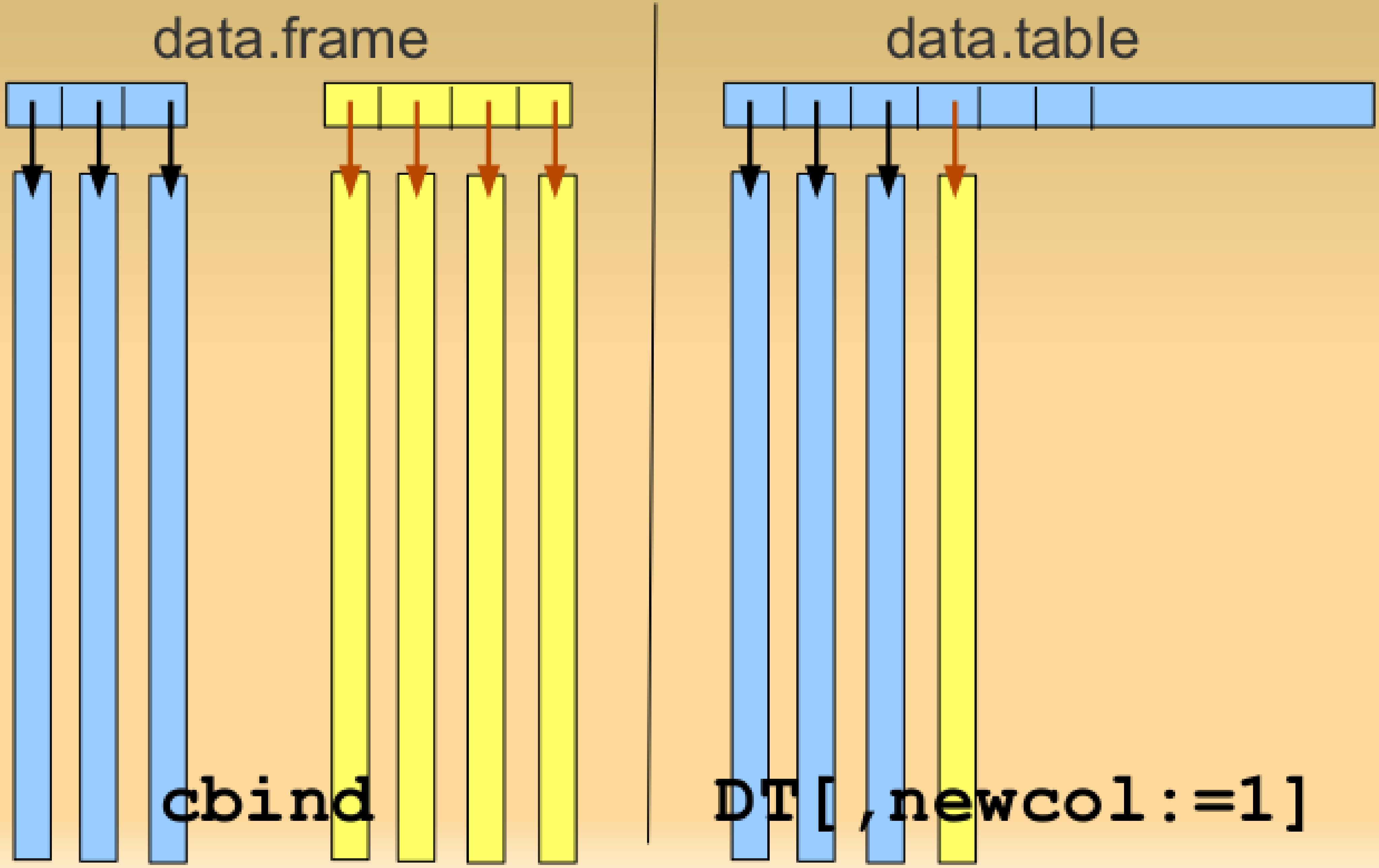
Since 2010, data.table :

- Allocates memory for largest group
- Reuses that same memory for all groups
- Allocates result data.table up front
- Implemented in C
- eval() of j within each group

Recent innovations

- Instead of the eval(j) from C, dplyr converts to an Rcpp function and calls that from C. Skipping the R eval step.
- In response, data.table now has **GForce**: one function call that computes the aggregate across groups. Called once only so no need to speed up many calls!
- Both approaches limited to simple aggregates: sum, mean, sd, etc. But often that's all that's needed.

data.table over-allocates



:= and `:=`()

```
DT[col1==something, col2:=col3+1]


DT[, `:=`(newCol1=mean(colA),
          newCol2=sd(colA)),
      by=sector]
```

`set*` functions

- `set()`
- `setattr()`
- `setnames()`
- `setcolorder()`
- `setkey()`
- `setkeyv()`

All options

datatable.verbose	FALSE
datatable.nomatch	NA_integer_
datatable.optimize	Inf
datatable.print.nrows	100L
datatable.print.topn	5L
datatable.allow.cartesian	FALSE
datatable.alloccol	quote(max(100L,ncol(DT)+64L))
datatable.integer64	"integer64"

All symbols

- `.N`
- `.SD`
- `.I`
- `.BY`
- `.GRP`

.SD

```
stocks[, head(.SD,2), by=sector]
```

```
stocks[, lapply(.SD, sum), by=sector]
```

```
stocks[, lapply(.SD, sum), by=sector,
.SDcols=c("mcap",paste0(revenueFQ",1:8))]
```

.I

```
if (length(err <- allocation[,
                 if(length(unique(Price))>1) .I,
                 by=stock ]$V1 )) {

  warning("Fills allocated to different
accounts at different prices! Investigate.")

  print(allocation[err])

} else {

  cat("Ok   All fills allocated to each
account at same price\n")

}
```

Analogous to SQL

```
DT[ where,
    select | update,
    group by ]
  [ having ]
  [ order by ]
  [ i, j, by ] ... [ i, j, by ]
```

New in v1.9.2 on CRAN

- 37 new features and 43 bug fixes
- set() can now add columns just like :=
- .SDcols “de-select” columns by name or position; e.g.,

  `DT[,lapply(.SD,mean),by=colA,.SDcols=-c(3,4)]`
- fread() a subset of columns
- fread() commands; e.g.,

  `fread("grep blah file.txt")`
- Speed gains

Radix sort for integer

- R's method=”radix” is not actually a radix sort … it's a counting sort. See ?setkey/Notes.
- data.table liked and used it, though.
- A true radix sort caters for range > 100,000
- (Negatives was a one line change to R we suggested and was accepted in R 3.1)
- Adapted to integer from Terdiman and Herf's code for float …

Radix sort for numeric

- R reminder: numeric == floating point numbers
- Radix Sort Revisited, Pierre Terdiman, 2000

  http://codercorner.com/RadixSortRevisited.htm
- Radix Tricks, Michael Herf, 2001

  http://stereopsis.com/radix.html
- Their C code now in data.table with minor changes; e.g., NA/NaN and 6-pass for double

Faster for those cases

20 million rows x 4 columns, 539MB

a & b (numeric), c (integer), d (character)

	v1.8.10	v1.8.11
setkey(DT, a)	54.9s	7.2s
setkey(DT, c)	48.0s	7.0s
setkey(DT, a, b)	102.3s	16.9s
”Cold” grouping (no setkey first) :		
DT[, mean(b), by=c]	47.0s	8.7s

https://gist.github.com/arunsrinivasan/7997273

New feature: melt/cast

i.e. reshape2 for data.table

20 million rows x 6 columns (a:f)	768MB
melt(**DF**, id=”d”, measure=1:2)	191 sec
melt(**DT**, id=“d”, measure=1:2)	3 sec
dcast(**DF**, d~e, ..., fun=sum)	184 sec
dcast(**DT**, d~e, ..., fun=sum)	28 sec

https://gist.github.com/arunsrinivasan/7839891

Similar to melt_ in Kmisc by Kevin Ushey

… melt/cast continued

Q: Why not submit a pull request to reshape2 ?

A: This C implementation calls data.table internals at C-level (e.g. fastorder, grouping, and joins). It makes sense for this code to be together.

Miscellaneous

```
DT[, (myvar):=NULL]
```

Space and specials; e.g., `by="a, b, c"`

```
DT[4:7,newCol:=8][]
```

- extra `[]` to print at prompt
- auto fills rows 1:3 with NA

53 examples in :

```
example(data.table)
```

Thank you

http://datatable.r-forge.r-project.org/

http://stackoverflow.com/questions/tagged/data.table

```
> install.packages(”data.table”)
> require(data.table)
> ?data.table
> ?fread
```

Learn by example :

```
> example(data.table)
```