data.table
an introduction
and best practices

Bill Gold

September 17th 2018

alternate title

data.table Where are We Going?

I. why data.table?

II. DT [i, j, by] [c] - syntax

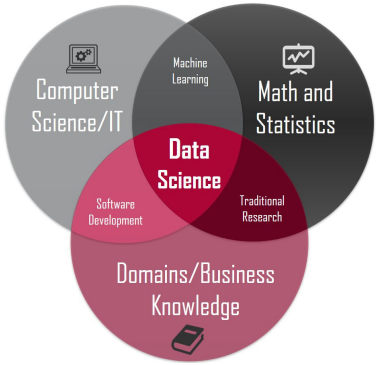
III. data exploration

IV. something unexpected

V. cool next steps imho

about bill

+$500MM ROI



Hundreds of Models

+10 Platforms

Ataeva

HAYSTREAM

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Today’s Presentation

https://github.com/billcgold/presentations/tree/master/data.table-nyhackr_2018-09-17

About data.table

- v1.0 released by CRAN in 2006
- by Matt Dowle et all
- high-performance version of data.frame
- 4th largest Stack Overflow tag for an R package

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fast

concise

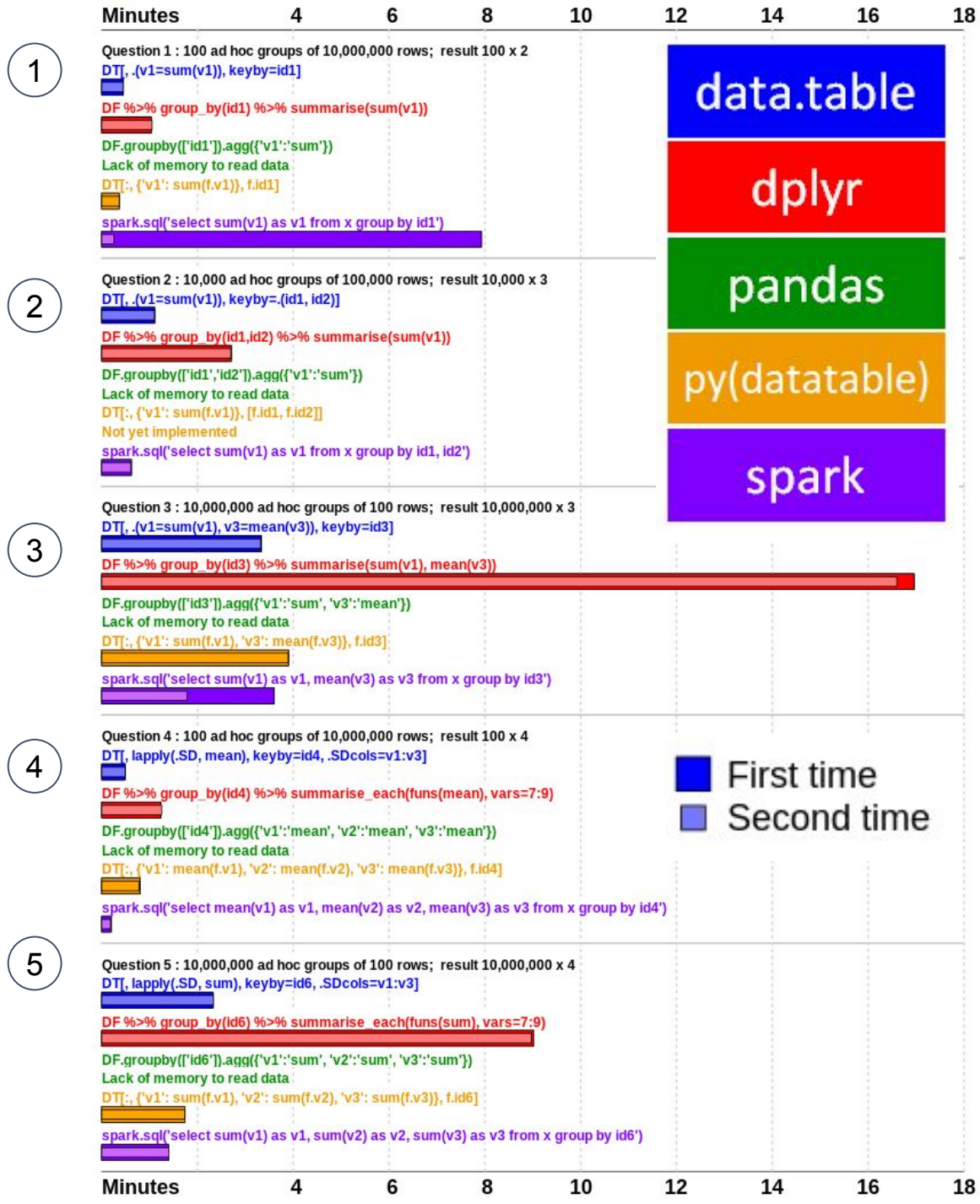
integrates well with R

fast is relative

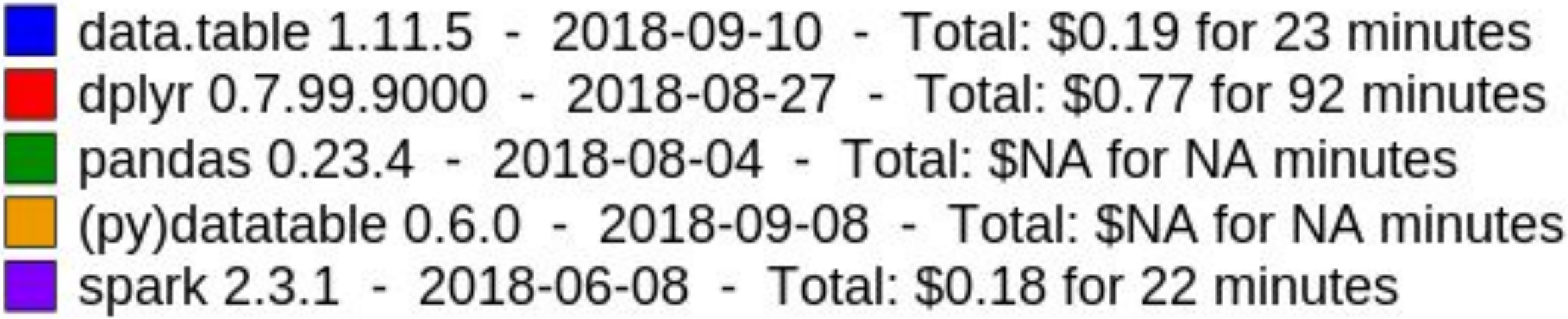
data.table is objectively fast

1B rows, 9 columns, 50GB

Web Benchmark Source
https://h2oai.github.io/db-benchmark/



fast



Web Benchmark Source
https://h2oai.github.io/db-benchmark/

why is this package different?

in memory

by reference

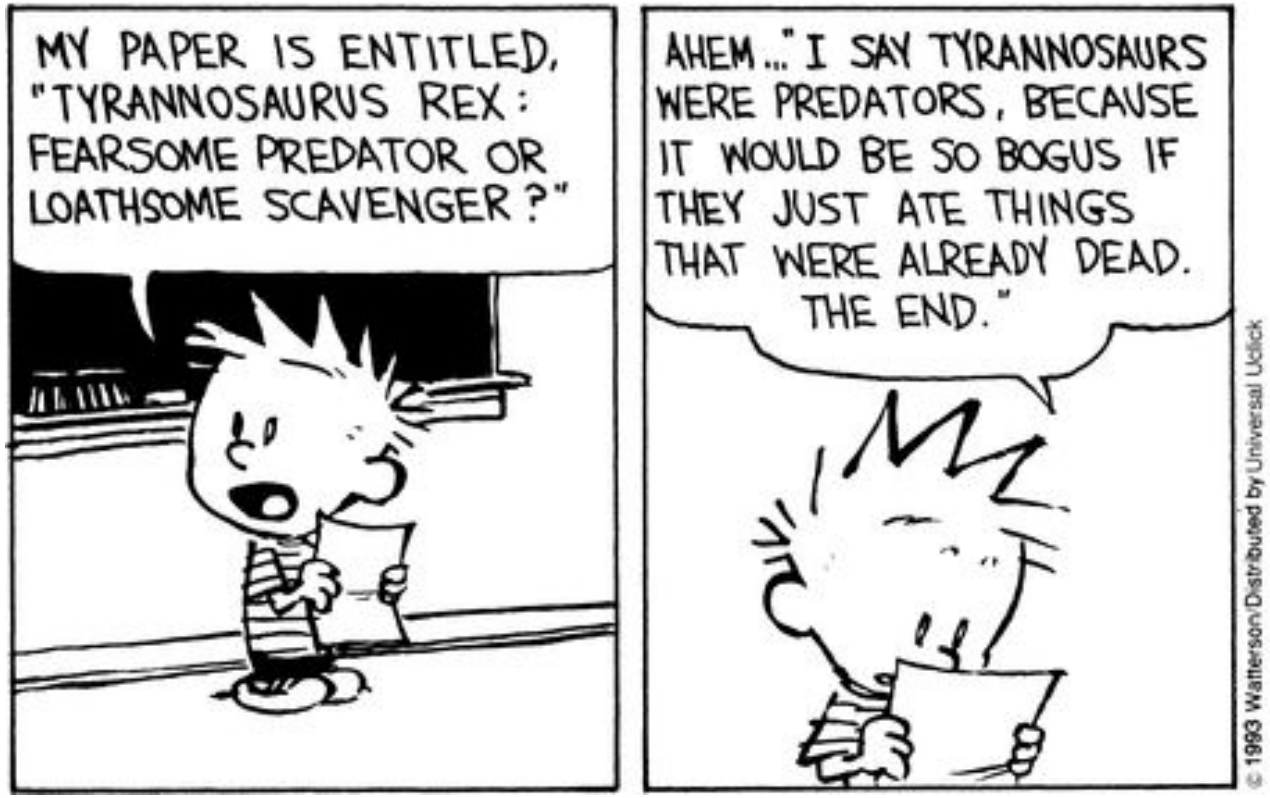
parallel processing (at times)

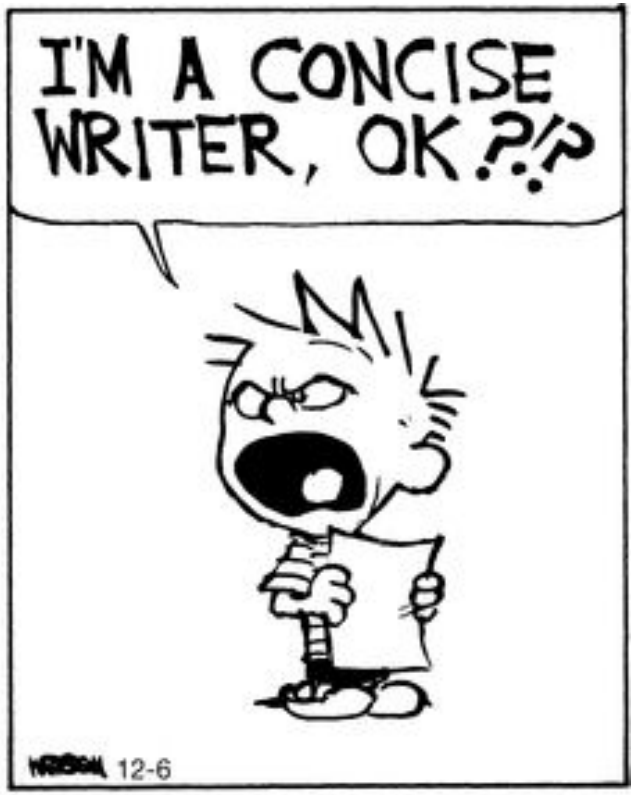
algorithms leveraging R's efficient internal structures (global character cache)

radix sorting from Terdiman and Herf, contributing back to base R

setkey contiguous, then use efficient contiguous methods

concise


MY PAPER IS ENTITLED, "TYRANNOSAURUS REX: FEARSOME PREDATOR OR LOATHSOME SCAVENGER?"
AHEM..." I SAY TYRANNOSAURS WERE PREDATORS, BECAUSE IT WOULD BE SO BOGUS IF THEY JUST ATE THINGS THAT WERE ALREADY DEAD. THE END."
© 1993 Watterson/Distributed by Universal Uclick


I'M A CONCISE WRITER, OK?!?
12-6

concise

aggregate & filter mtcars ...

```
   cyl mpg-mean
1:   6 20.56667
2:   4 28.07500
3:   8 15.40000
```

concise

sql

```
SELECT    cyl, mean (mpg)
FROM      mtcars
WHERE     am = 1
GROUP BY  cyl
```

65 characters
27 repetitive

concise

data.frame

```
aggregate (
        mtcars$mpg [ mtcars$am==1]
      , by = list (cyl=mtcars$cyl[ mtcars$am==1] )
      , FUN = mean )
```

function-centric

89 characters
41 repetitive

concise

data.table

```
mtcars [ am == 1, mean (mpg), cyl ]
```

data-centric

27 characters
4 repetitive

concise

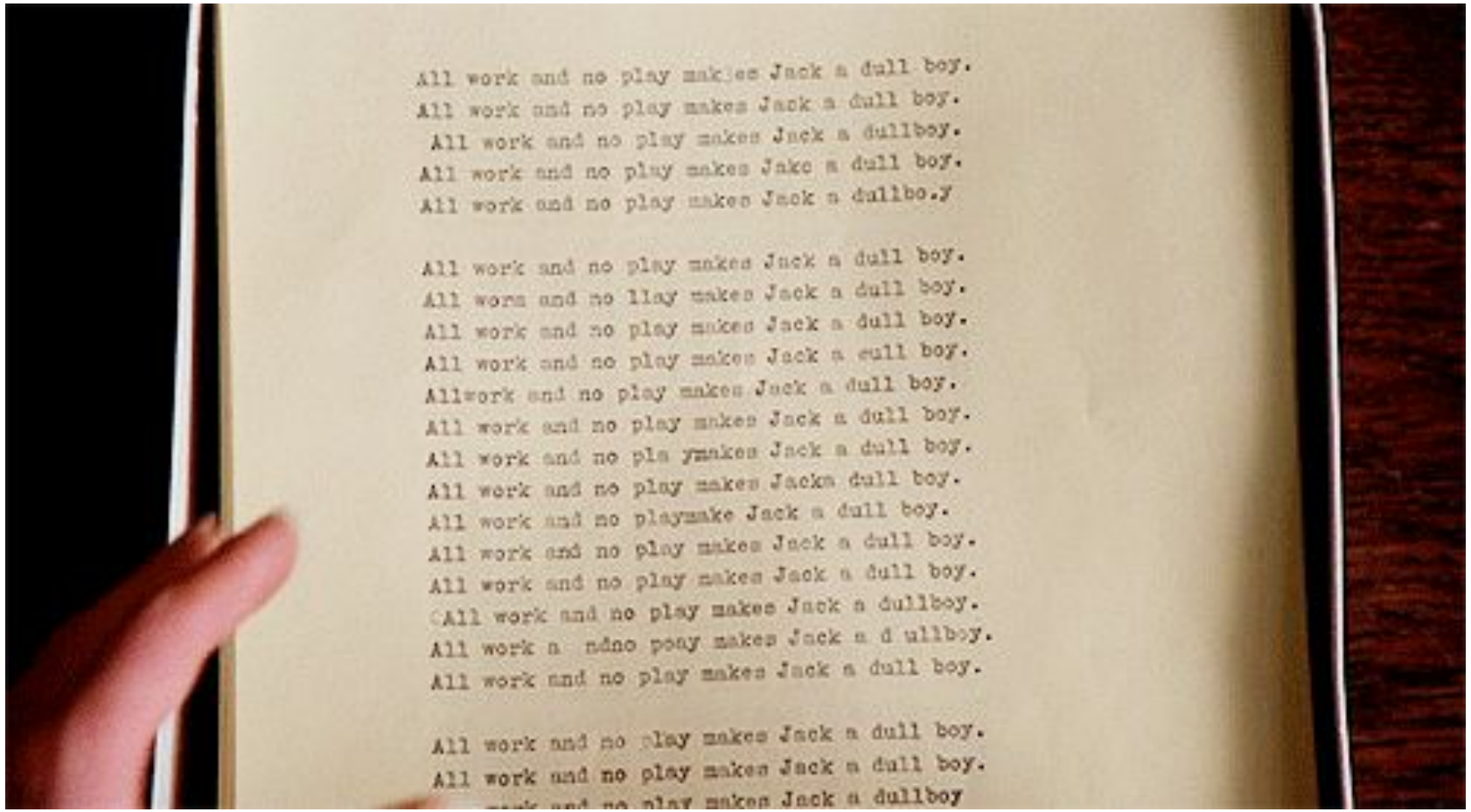
~ 1:6

6 vs 34

data.table vs SQL

count of repetitive characters

concise


All work and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dullboy.
All work and no play makes Jake a dull boy.
All work and no play makes Jack a dullbo.y
All work and no play makes Jack a dull boy.
All work and no llay makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
Allwork and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no pla ymakes Jack a dull boy.
All work and no play makes Jackn dull boy.
All work and no playmake Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dullboy.
All work a ndno pony makes Jack a d ullboy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dull boy.
All work and no play makes Jack a dullboy

“any R function from any R package can be used in queries”

Matt Dowle

data.table Where are We Going?

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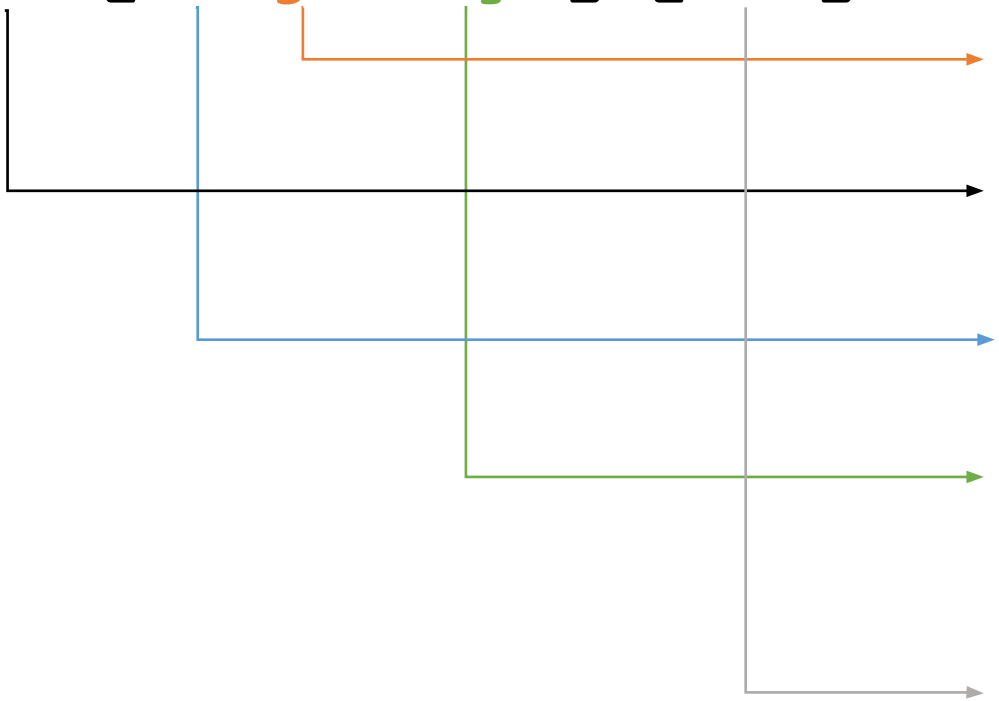
data.table and SQL SELECT

DT [i, j, by] [c]



SELECT	select-list
FROM	table
WHERE	row filters
GROUP BY	aggregates
ORDER BY	
HAVING	aggregate + filter

setup example

```
library(data.table)

dt.mtcars <- data.table ( mtcars, keep.rownames=T )
```

filter

```
dt.mtcars [ cyl == 8 ]
```

```
                    rn  mpg cyl  disp  hp drat    wt  qsec vs am gear carb
 1:    Hornet Sportabout 18.7   8 360.0 175 3.15 3.440 17.02  0  0    3    2
 2:              Duster 360 14.3   8 360.0 245 3.21 3.570 15.84  0  0    3    4
 3:              Merc 450SE 16.4   8 275.8 180 3.07 4.070 17.40  0  0    3    3
 4:              Merc 450SL 17.3   8 275.8 180 3.07 3.730 17.60  0  0    3    3
 5:             Merc 450SLC 15.2   8 275.8 180 3.07 3.780 18.00  0  0    3    3
 6:  Cadillac Fleetwood 10.4   8 472.0 205 2.93 5.250 17.98  0  0    3    4
 7: Lincoln Continental 10.4   8 460.0 215 3.00 5.424 17.82  0  0    3    4
 8:   Chrysler Imperial 14.7   8 440.0 230 3.23 5.345 17.42  0  0    3    4
 9:    Dodge Challenger 15.5   8 318.0 150 2.76 3.520 16.87  0  0    3    2
10:         AMC Javelin 15.2   8 304.0 150 3.15 3.435 17.30  0  0    3    2
11:          Camaro Z28 13.3   8 350.0 245 3.73 3.840 15.41  0  0    3    4
12:    Pontiac Firebird 19.2   8 400.0 175 3.08 3.845 17.05  0  0    3    2
13:      Ford Pantera L 15.8   8 351.0 264 4.22 3.170 14.50  0  1    5    4
14:       Maserati Bora 15.0   8 301.0 335 3.54 3.570 14.60  0  1    5    8
```

filter multiple conditions

```
dt.mtcars [ cyl == 8   &
            wt < 4   &
            rn %like% 'Merc' ]
```

```
                rn  mpg cyl  disp  hp drat   wt qsec vs am gear carb
1:  Merc 450SL 17.3   8 275.8 180 3.07 3.73 17.6  0  0    3    3
2: Merc 450SLC 15.2   8 275.8 180 3.07 3.78 18.0  0  0    3    3
```

filter row numbers

```
dt.mtcars [ 1:5 ]
```

```
                  rn  mpg cyl disp  hp drat    wt  qsec vs am gear carb
1:          Mazda RX4 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
2:      Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
3:         Datsun 710 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
4:     Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
5: Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
```

select-clause vector output

```
dt.mtcars [ , rn ]
```

```
 [1] "Mazda RX4"           "Mazda RX4 Wag"       "Datsun 710"          "Hornet 4 Drive"
 [5] "Hornet Sportabout"   "Valiant"             "Duster 360"          "Merc 240D"
 [9] "Merc 230"            "Merc 280"            "Merc 280C"           "Merc 450SE"
[13] "Merc 450SL"          "Merc 450SLC"         "Cadillac Fleetwood"  "Lincoln Continental"
[17] "Chrysler Imperial"   "Fiat 128"            "Honda Civic"         "Toyota Corolla"
[21] "Toyota Corona"       "Dodge Challenger"    "AMC Javelin"         "Camaro Z28"
[25] "Pontiac Firebird"    "Fiat X1-9"           "Porsche 914-2"       "Lotus Europa"
[29] "Ford Pantera L"      "Ferrari Dino"        "Maserati Bora"       "Volvo 142E"
```

select-clause vector output

```
# same as previous, much faster
dt.mtcars [["rn"]]
```

```
 [1] "Mazda RX4"           "Mazda RX4 Wag"       "Datsun 710"          "Hornet 4 Drive"
 [5] "Hornet Sportabout"   "Valiant"             "Duster 360"          "Merc 240D"
 [9] "Merc 230"            "Merc 280"            "Merc 280C"           "Merc 450SE"
[13] "Merc 450SL"          "Merc 450SLC"         "Cadillac Fleetwood"  "Lincoln Continental"
[17] "Chrysler Imperial"   "Fiat 128"            "Honda Civic"         "Toyota Corolla"
[21] "Toyota Corona"       "Dodge Challenger"    "AMC Javelin"         "Camaro Z28"
[25] "Pontiac Firebird"    "Fiat X1-9"           "Porsche 914-2"       "Lotus Europa"
[29] "Ford Pantera L"      "Ferrari Dino"        "Maserati Bora"       "Volvo 142E"
```

select-clause data.table output

```
dt.mtcars [ 1:5 , list (rn) ]
```

```
                  rn
1:          Mazda RX4
2:      Mazda RX4 Wag
3:         Datsun 710
4:     Hornet 4 Drive
5: Hornet Sportabout
```

select-clause data.table output

```
dt.mtcars [ 1:5 , list (rn, cyl, hp) ]
```

```
                  rn cyl  hp
1          Mazda RX4   6 110
2      Mazda RX4 Wag   6 110
3         Datsun 710   4  93
4     Hornet 4 Drive   6 110
5 Hornet Sportabout   8 175
```

4 selects
1 result

4 selects 1 result

```
dt.mtcars [ , list (rn, cyl, hp) ]

dt.mtcars [ , . (rn, cyl, hp) ]    # .() = list()

dt.mtcars [ , c ('rn', 'cyl', 'hp'), with = F ]

dt.mtcars [ , c ( 1, 3, 5) ]
```

select-clause data.table output

```
dt.mtcars [ 1:5 , .SD, .SDcols = rn:cyl ]
```

```
               rn  mpg cyl
1:   Datsun 710 22.8   4
2:    Merc 240D 24.4   4
3:     Merc 230 22.8   4
4:     Fiat 128 32.4   4
5: Honda Civic 30.4   4
```

variable column names ..

```
variable.col.name <- 'rn'
dt.mtcars [ 1:5 , ..variable.col.name ]
```

```
                  V1
1:          Mazda RX4
2:      Mazda RX4 Wag
3:         Datsun 710
4:     Hornet 4 Drive
5: Hornet Sportabout
```

group by

```
dt.mtcars [ , . (mean(mpg)), by = cyl ]
```

```
   cyl       V1
1:   6 19.74286
2:   4 26.66364
3:   8 15.10000
```

group by (cont'd)

```
dt.mtcars [ , . ( mpg = mean(mpg)), by = cyl ]
```

```
   cyl      mpg
1:   6 19.74286
2:   4 26.66364
3:   8 15.10000
```

group by (cont'd)

```
dt.mtcars [ , lapply ( .SD, mean )
          , .SDcols = mpg:carb
          , by = cyl ]
```

```
   cyl      mpg cyl     disp        hp     drat       wt     qsec        vs        am     gear     carb
1:   6 19.74286   6 183.3143 122.28571 3.585714 3.117143 17.97714 0.5714286 0.4285714 3.857143 3.428571
2:   4 26.66364   4 105.1364  82.63636 4.070909 2.285727 19.13727 0.9090909 0.7272727 4.090909 1.545455
3:   8 15.10000   8 353.1000 209.21429 3.229286 3.999214 16.77214 0.0000000 0.1428571 3.285714 3.500000
```

what's different?

chaining

having (chaining)

```
dt.mtcars [ , .(mpg = mean(mpg)), by=cyl ] [ mpg > 16 ]
```

```
   cyl      mpg
1:   6 19.74286
2:   4 26.66364
```

order by

```
dt.mtcars [,.(mpg = mean(mpg)),by=cyl] [order(-mpg)]
```

```
   cyl      mpg
1:   4 26.66364
2:   6 19.74286
3:   8 15.10000
```

what's our vector Victor?

vectors and %in%

```
1:2
1:6
1:2 %in% 1:6
1:6 %in% 1:2
```

```
> 1:2
[1] 1 2
> 1:6
[1] 1 2 3 4 5 6
> 1:2 %in% 1:6
[1] TRUE TRUE
> 1:6 %in% 1:2
[1]  TRUE  TRUE FALSE FALSE FALSE FALSE
```

vectors and %in% (cont'd)

```
dt.mtcars [ , cyl ]
dt.mtcars [ , cyl ] %in% c(4,6)
```

```
> dt.mtcars [ , cyl ]
 [1] 6 6 4 6 8 6 8 4 4 6 6 8 8 8 8 8 8 4 4 4 4 8 8 8 8 4 4 4 8 6 8 4
> dt.mtcars [ , cyl ] %in% c(4,6)
 [1]  TRUE  TRUE  TRUE  TRUE FALSE  TRUE FALSE  TRUE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE
[16] FALSE FALSE  TRUE  TRUE  TRUE  TRUE FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE FALSE  TRUE
[31] FALSE  TRUE
```

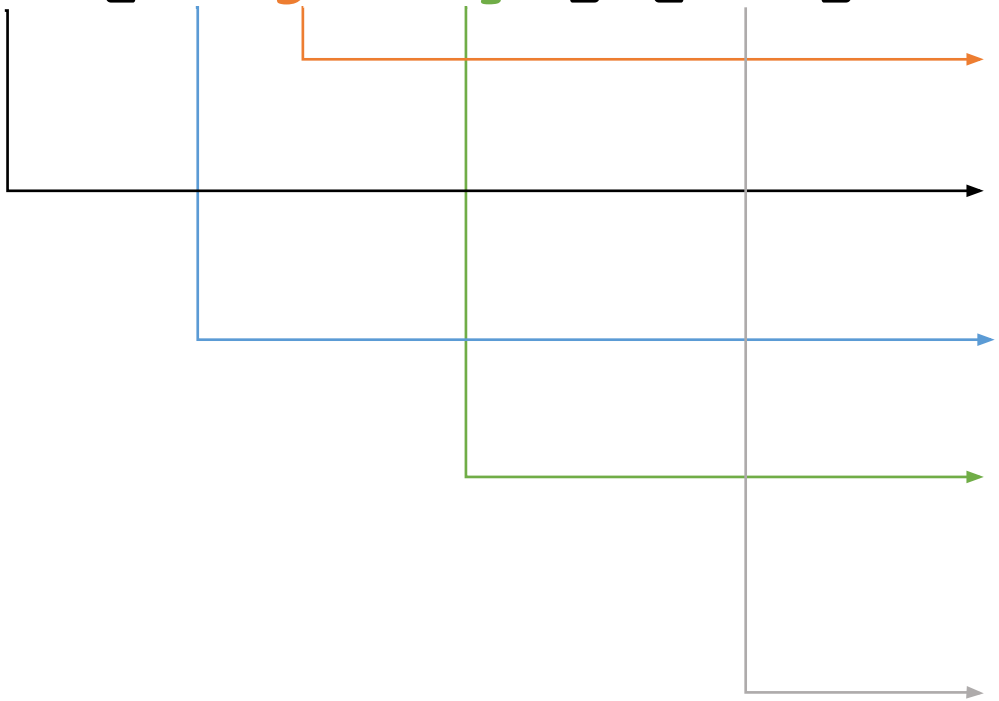
filters vectors %in%

```
dt.mtcars [ cyl %in% c(4,6) ]   [ 1:5 ]   [ order (cyl) ]
```

```
                rn  mpg cyl disp  hp drat    wt  qsec vs am gear carb
1:      Datsun 710 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
2:       Mazda RX4 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
3:  Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
4: Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
5:         Valiant 18.1   6  225 105 2.76 3.460 20.22  1  0    3    1
```

data.table and SQL SELECT

DT [i, j, by] [c]



SELECT	select-list
FROM	table
WHERE	row filters
GROUP BY	aggregates
ORDER BY	
HAVING	aggregate + filter

join

```
dt.mtcars.cyl.aggr <- dt.mtcars [ ,  .  (mpg.mean.cyl=mean(mpg)
                                         , mpg.sd.cyl=sd(mpg)
                                         , hp.mean.cyl=mean(hp)
                                         , hp.sd.cyl=sd(hp))
                                  , by = cyl ]
```

```
> dt.mtcars.cyl.aggr
   cyl mpg.mean.cyl mpg.sd.cyl hp.mean.cyl hp.sd.cyl
1:   4     26.66364   4.509828    82.63636  20.93453
2:   6     19.74286   1.453567   122.28571  24.26049
3:   8     15.10000   2.560048   209.21429  50.97689
```

join (cont'd)

```
setkeyv ( dt.mtcars, c('cyl') )
setkeyv ( dt.mtcars.cyl.aggr, c('cyl') )

DT <- dt.mtcars [ dt.mtcars.cyl.aggr ]
DT [ 1:5 ]
```

```
               rn  mpg cyl  disp hp drat    wt  qsec vs am gear carb mpg.mean.cyl mpg.sd.cyl hp.mean.cyl hp.sd.cyl
1:     Datsun 710 22.8   4 108.0 93 3.85 2.320 18.61  1  1    4    1     26.66364   4.509828     82.63636  20.93453
2:      Merc 240D 24.4   4 146.7 62 3.69 3.190 20.00  1  0    4    2     26.66364   4.509828     82.63636  20.93453
3:       Merc 230 22.8   4 140.8 95 3.92 3.150 22.90  1  0    4    2     26.66364   4.509828     82.63636  20.93453
4:       Fiat 128 32.4   4  78.7 66 4.08 2.200 19.47  1  1    4    1     26.66364   4.509828     82.63636  20.93453
5:    Honda Civic 30.4   4  75.7 52 4.93 1.615 18.52  1  1    4    2     26.66364   4.509828     82.63636  20.93453
```

join (cont'd)

JOIN type	DT syntax	data.table::merge() syntax
INNER	X[Y, nomatch=0]	merge(X, Y, all=FALSE)
LEFT OUTER	Y[X]	merge(X, Y, all.x=TRUE)
RIGHT OUTER	X[Y]	merge(X, Y, all.y=TRUE)
FULL OUTER	-	merge(X, Y, all=TRUE)
FULL OUTER WHERE NULL (NOT INNER)	-	merge(X, Y, all=TRUE), subset NA

Source: Ronald Stalder
https://rstudio-pubs-static.s3.amazonaws.com/52230_5ae0d25125b544caab32f75f0360e775.html

.	list
..	variable select-list
X[Y]	right outer join

:D big grin

:o) clown

:= update

concise

update

```
SELECT      cyl, mpg, am
FROM        mtcars
WHERE       am = 1
```

=

```
UPDATE
SET         cyl = 1
FROM        mtcars
WHERE       am = 1
```

:=

update add a new column :=

```
dt.mtcars [ , N := 1 ]
dt.mtcars [ 1:5 ]
```

```
                  rn  mpg cyl disp  hp drat    wt  qsec vs am gear carb N
1:          Mazda RX4 21.0   6  160 110 3.90 2.620 16.46  0  1    4    4 1
2:      Mazda RX4 Wag 21.0   6  160 110 3.90 2.875 17.02  0  1    4    4 1
3:         Datsun 710 22.8   4  108  93 3.85 2.320 18.61  1  1    4    1 1
4:     Hornet 4 Drive 21.4   6  258 110 3.08 3.215 19.44  1  0    3    1 1
5: Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2 1
```

update :=

```
v.manufacturer <- gsub("([A-Za-z]+).*"
                       , "\\1"
                       , dt.mtcars [ , rn ] )
dt.mtcars [ , manufacturer := v.manufacturer ]
dt.mtcars [ 1:5 ]
```

	rn	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb	N	manufacturer
1:	Mazda RX4	21.0	6	160	110	3.90	2.620	16.46	0	1	4	4	1	Mazda
2:	Mazda RX4 Wag	21.0	6	160	110	3.90	2.875	17.02	0	1	4	4	1	Mazda
3:	Datsun 710	22.8	4	108	93	3.85	2.320	18.61	1	1	4	1	1	Datsun
4:	Hornet 4 Drive	21.4	6	258	110	3.08	3.215	19.44	1	0	3	1	1	Hornet
5:	Hornet Sportabout	18.7	8	360	175	3.15	3.440	17.02	0	0	3	2	1	Hornet

update :=

```
dt.mtcars [ manufacturer == 'Merc', is.merc := 1 ]

dt.mtcars [ , .N, by = is.merc ]
```

```
> dt.mtcars [ , .N, by = is.merc ]
   is.merc  N
1:      NA 25
2:       1  7
```

other functions

```
fread
fwrite
readRDS
saveRDS

setnames
setcolorder

dcast & melt

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

```
format.q
round
```

```
DT [ i, j, by ] [ c ]

DT [  where,
      select-clause,
      group by ] [ order | having ]
```

data.table Where are We Going?

I. why data.table?

II. DT [i, j, by] [c] - syntax

III. data exploration

IV. something unexpected

V. cool next steps imho

time series aggregate

```
#########################################################################
#### calculate percentile variables
#########################################################################
cutoffs <- c(0:10)/10
by.vars <-  c('FactorId.01', 'FactorId.02')
setkeyv (time.series, by.vars)
quantile.time.series <- time.series [  Period >= '2008-01-01'
                                     , . (  Variable.01      =  quantile (  Variable.01, cutoffs, na.rm = T )
                                          ,  Variable.02     =  quantile (  Variable.02, cutoffs, na.rm = T )
                                          ,  Variable.03     =  quantile (  Variable.03, cutoffs, na.rm = T )
                                          ,  Variable.04     =  quantile (  Variable.04, cutoffs, na.rm = T )
                                          ,  Variable.05     =  quantile (  Variable.05, cutoffs, na.rm = T )
                                          ,  Variable.06     =  quantile (  Variable.06, cutoffs, na.rm = T )
                                     , by = by.vars ]
```

scoring code

```
1  ##################################################################################
2  #### score a probit model
3  ##################################################################################
4
5  time.series [ , infinity.war.exp   := (- 8675309
6                                         + captain.america * 0.1111
7                                         + wonder.woman * 0.2222
8                                         + iron.man * 0.3333
9                                         + spider.man * 0.4444
10                                        + the.hulk * 0.5555
11                                        + aqua.man * -0.6666 ) ]
12
13 time.series [ , infinity.war.score := exp (exp.equation) / ( 1 + exp(exp.equation) ) ]
14
```

enhanced data dictionary (edd)

```
display.data ( edd (
      dt = data.table (iris)
      , path_out = '/home/bill/'
      , file_out = 'iris.edd'
      , return_edd = T )  )
```

Show 15 entries Search:

	col_name	col_type	num_unique	num_na	num_blank	fill_rate	edd_mean	edd_pctl_01	edd_pctl_05	edd_pctl_25	edd_pctl_75	edd_pctl_95	edd_pctl_99	edd_sum	frequency_10	first_row
	A		All		All		All	All	All	All	All	All	All	,	All	
1	Sepal.Length	numeric	35	0		1.00	5.84333333333333	4.4	4.6	5.1	6.4	7.255	7.7	876.5	5:10,5.1:9,6.3:9,5.7:8,6.7:8,5.5:7,5.8:7,6.4:7,4.9:6,5.4:6,	5.1
2	Sepal.Width	numeric	23	0		1.00	3.05733333333333	2.2	2.345	2.8	3.3	3.8	4.151	458.6	3:26,2.8:14,3.2:13,3.4:12,3.1:11,2.9:10,2.7:9,2.5:8,3.3:6,3.5:6,	3.5
3	Petal.Length	numeric	43	0		1.00	3.758	1.149	1.3	1.6	5.1	6.1	6.7	563.7	1.4:13,1.5:13,4.5:8,5.1:8,1.3:7,1.6:7,5.6:6,4.5:4,4.7:5,4.9:5,	1.4
4	Petal.Width	numeric	22	0		1.00	1.19933333333333	0.1	0.2	0.3	1.8	2.3	2.5	179.9	0.2:29,1.3:13,1.5:12,1.8:12,1.4:8,2.3:8,0.3:7,0.4:7,1:7,2:6,	0.2
5	Species	factor	3	0	0	1.00									setosa:50,versicolor:50,virginica:50,	1

Showing 1 to 5 of 5 entries Previous 1 Next

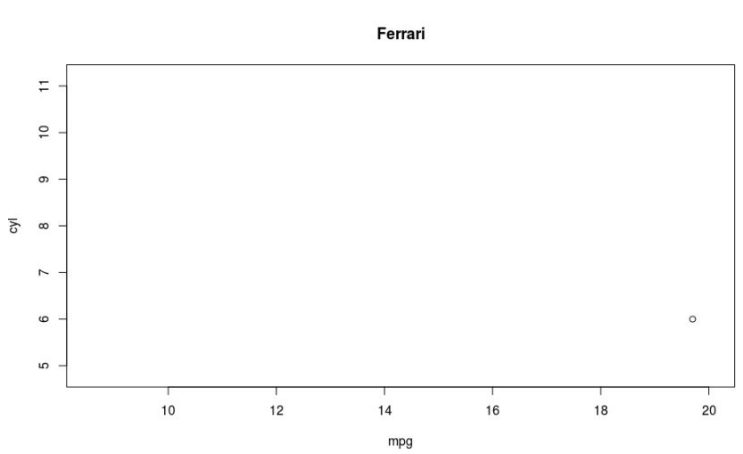
intersection of multiple data.tables

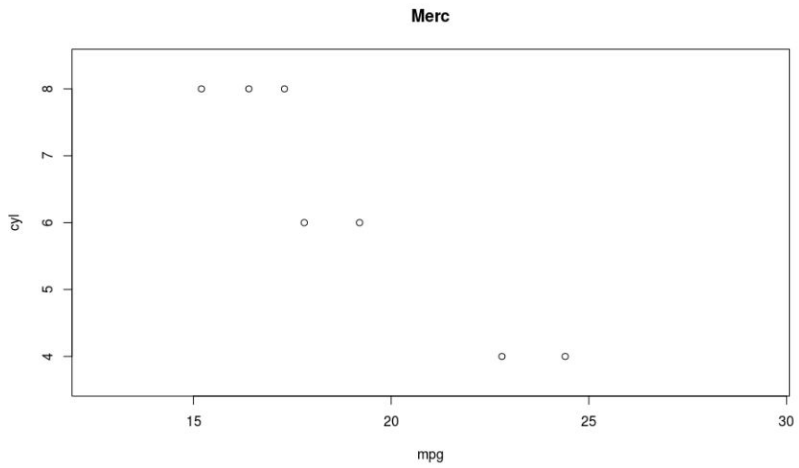
```
venn.diagram ( dt.mtcars [ , carb ]
             , dt.mtcars [ , gear ]
             , 'carb'
             , 'gear' )
```

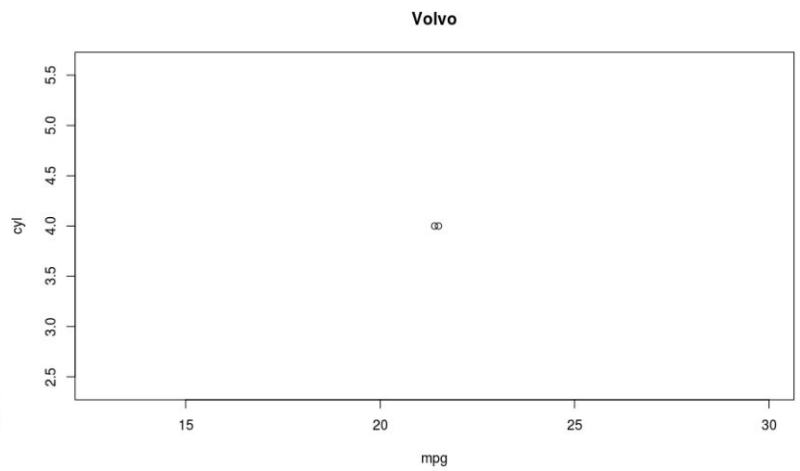
```
Union:                  7
carb Only:              4
Intersection:           2
gear Only:              1
```

data.table & plot

```
dt.mtcars [ , plot ( x = mpg
                   , y = cyl
                   , main = manufacturer )
            , keyby = manufacturer ]
```





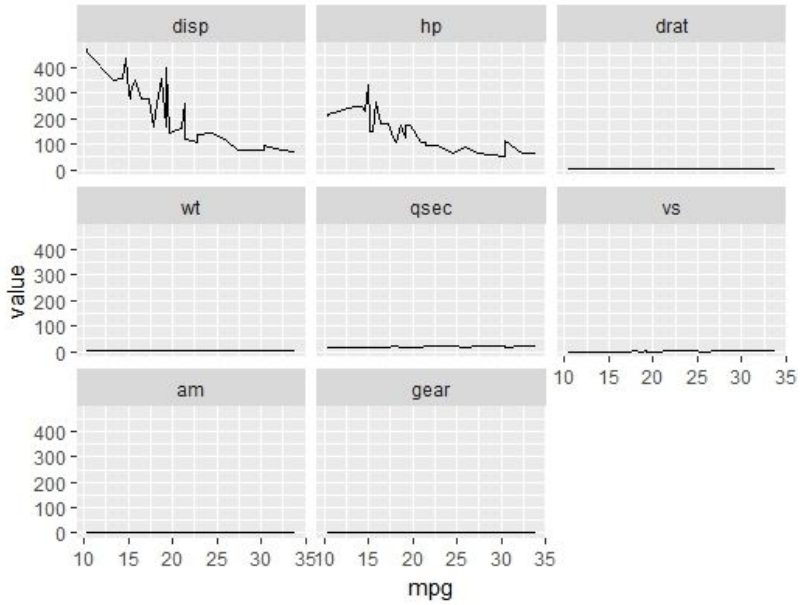


...

data.table & ggplot

```
plot.All.XY.by.Z <- function (dt, x, y, z) {
  #  numerics only
  dt[, (y):= lapply( .SD, function(x) {as.numeric(as.character(x))}), .SDcols = y]
  dts <- melt(dt, id = c(x,z), measure = y)
  p <- ggplot(dts, aes_string(x = colnames(dt)[x], y = "value", colours = colnames(dt)[z])) +
    geom_line() +
    facet_wrap(~ variable)
  print (p)
}

plot.All.XY.by.Z ( dt.mtcars, x=2, y=4:11, z=2)
```



Source - SO akash87
https://stackoverflow.com/questions/44509287/best-way-to-plot-automatically-all-data-table-columns-using-ggplot2

Where are We Going?

I. why data.table? fast, concise, integrated

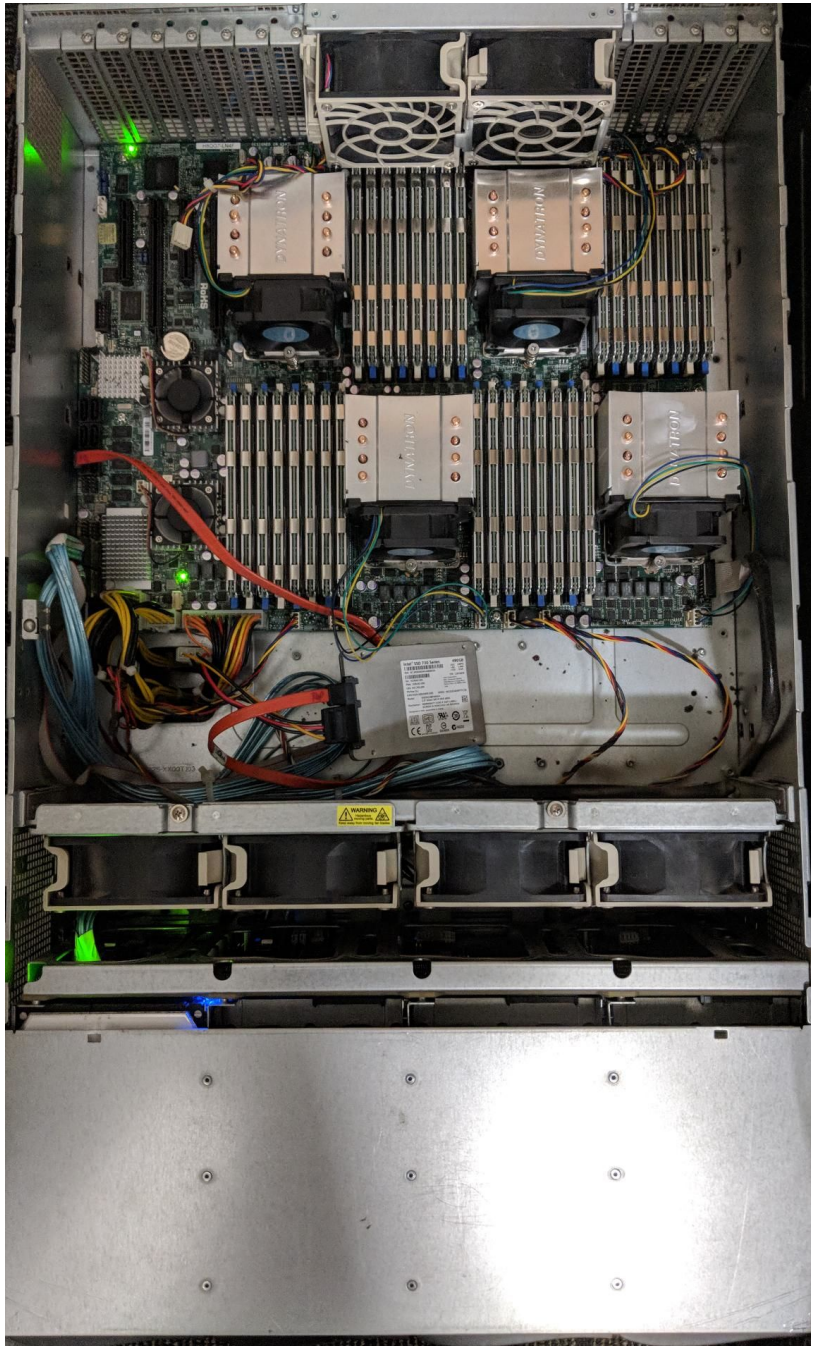
II. syntax - getting comfortable - DT [i, j, by] [c]

III. data.table and data exploration

IV. something unexpected

V. cool next steps

unexpected



unexpected

- 4 CPUs
- 40 Terabytes of disk - RAID6
- 1 Terabyte of RAM
- 6k cores

Out of Pocket Cost $21k

Where are We Going?

I. why data.table? fast, concise, integrated

II. syntax - getting comfortable - DT [i, j, by] [c]

III. data.table and data exploration

IV. something unexpected (economics)

V. cool next steps

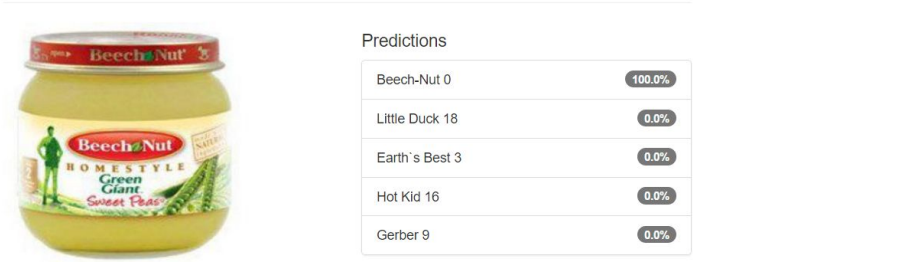
43x Performance Increase Based on GPU

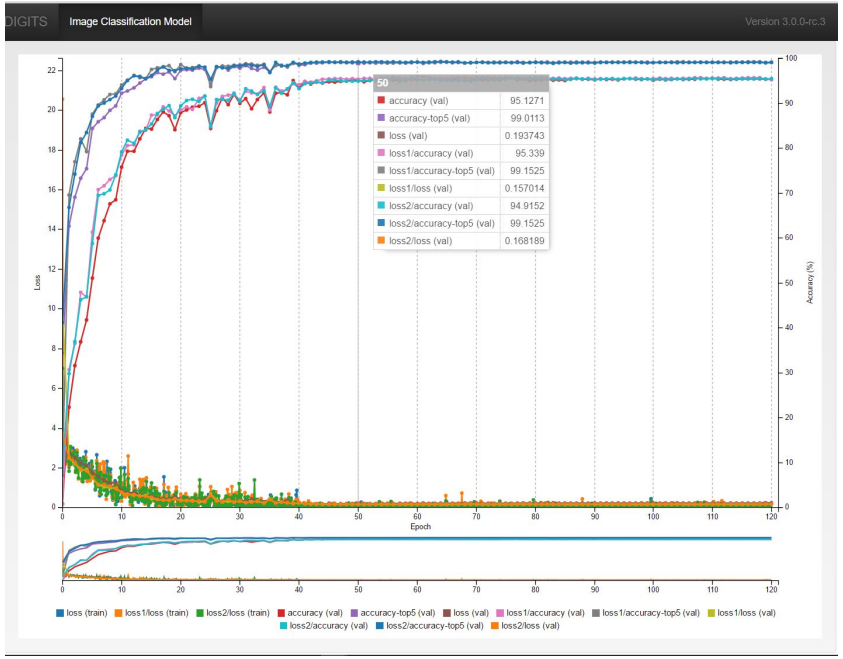
- Transition Migration Matrices
- Time to Execute
  - Pre-migration ~2.5 days
  - Post-migration < 1s

	Cores		
	32		6k
rows	R (sec)	Python (sec)	Python (sec)
100k	0.7	1.6	0.06
500k	2.8	9.2	0.3
1 MM	6.4	17.5	0.7
2 MM	12.1	36.6	0.9
5 MM	26.3	84.3	2.1
10 MM	56.2	172.5	4.1

computer vision & retail products

Test Image





@ 50 Epochs

95% Accuracy


T. HANKS