ORACLE

# Session 2: OML4R 1.5.1 Transparency Layer

## With Oracle Machine Learning

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# Agenda

1. Introduction
2. Transparency Layer examples
3. Options for connecting to Oracle Database
4. R object persistence in Oracle Database
5. Support for Time Series data preparation
6. Ordering Framework
7. Global options
8. In-database sampling and random partitioning
9. Data types

# What does “transparency” mean?

# Transparency

*The Transparency Layer supports in-database data exploration, data preparation, and data analysis en route to application of machine learning algorithms, where we have a mix of in-database and open source R techniques.*

No need to learn a different programming paradigm or environment

Operate on database tables as though they were R objects using R syntax

Minimize change to base R scripts for database data

Implicitly translate R to SQL for in-database execution, performance, and scalability

# OML4R Packages

Transparency Layer

| Package | Description |
|---|---|
| ORE | Top Level Package for Oracle R Enterprise |
| OREbase | Corresponds to R's base package |
| OREstats | Corresponds to R's stat package |
| OREgraphics | Corresponds to R's graphics package |
| OREcommon | Common low-level functionality |
| OREdplyr | …must explicitly load package |
| OREeda | Exploratory data analysis package containing Base SAS PROC-equivalent functionality |
| OREembed | Embedded R Execution functionality |
| OREdm | Exposes Oracle Data Mining algorithms |
| OREmodels | ORE-provided advanced analytics algorithms |
| OREpredict | Enables scoring data in Oracle DB using R models |
| OREserver | Supports server-side functionality of OML4R |
| OERxml | Supports XML translation between R and Oracle Database |

# Documentation and Demos

```
OREShowDoc()

demo(package = "ORE")

demo("aggregate", package = "ORE")
```

# Demos in package 'ORE'

| | |
|---|---|
| aggregate | Aggregation |
| analysis | Basic analysis & data processing operations |
| basic | Basic connectivity to database |
| binning | Binning logic |
| columnfns | Column functions |
| cor | Correlation matrix |
| crosstab | Frequency cross tabulations |
| datastore | DataStore operations |
| datetime | Date/Time operations |
| derived | Handling of derived columns |
| distributions | Distribution, density, and quantile functions |
| do_eval | Embedded R processing |
| esm | Exponential smoothing method |
| freqanalysis | Frequency cross tabulations |
| glm | Generalized Linear Models |
| graphics | Demonstrates visual analysis |
| group_apply | Embedded R processing by group |
| hypothesis | Hyphothesis testing functions |
| matrix | Matrix related operations |
| nulls | Handling of NULL in SQL vs. NA in R |
| odm_ai | Oracle Data Mining: attribute importance |
| odm_ar | Oracle Data Mining: association rules |
| odm_dt | Oracle Data Mining: decision trees |
| odm_glm | Oracle Data Mining: generalized linear models |
| odm_kmeans | Oracle Data Mining: enhanced k-means clustering |
| odm_nb | Oracle Data Mining: naive Bayes classification |
| odm_nmf | Oracle Data Mining: non-negative matrix factorization |
| odm_oc | Oracle Data Mining: o-cluster |
| odm_svm | Oracle Data Mining: support vector machines |
| ore_dplyr | Data manipulation similar to dplyr |
| pca | Principal Component Analysis |
| push_pull | RDBMS <-> R data transfer |
| randomForest | Random Forest classification algortihm |
| rank | Attributed-based ranking of observations |
| reg | Ordinary least squares linear regression |
| row_apply | Embedded R processing by row chunks |
| sampling | Random row sampling and partitioning |
| script | |
| sql_like | Mapping of R to SQL commands |
| stepwise | Stepwise OLS linear regression |
| summary | Summary functionality |
| table_apply | Embedded R processing of entire table |

# Proxy objects for Big Data

data.frame

*Inherits from*

*Proxy*
ore.frame

| | Sepal.Length | Sepal.Width | Petal.Length | Petal.Width | Species |
|---|---|---|---|---|---|
| 1 | 5.1 | 3.5 | 1.4 | 0.2 | setosa |
| 2 | 4.9 | 3.0 | 1.4 | 0.2 | setosa |
| 3 | 4.7 | 3.2 | 1.3 | 0.2 | setosa |
| 4 | 4.6 | 3.1 | 1.5 | 0.2 | setosa |
| 5 | 5.0 | 3.6 | 1.4 | 0.2 | setosa |
| 6 | 5.4 | 3.9 | 1.7 | 0.4 | setosa |

```
> str(iris)
'data.frame':	150 obs. of  5 variables:
 $ Sepal.Length: num  5.1 4.9 4.7 4.6 5 5.4 4.6 5 4.4 4.9 ...
 $ Sepal.Width : num  3.5 3 3.2 3.1 3.6 3.9 3.4 3.4 2.9 3.1 ...
 $ Petal.Length: num  1.4 1.4 1.3 1.5 1.4 1.7 1.4 1.5 1.4 1.5 ...
 $ Petal.Width : num  0.2 0.2 0.2 0.2 0.2 0.4 0.3 0.2 0.2 0.1 ...
 $ Species     : Factor w/ 3 levels "setosa","versicolor",..: 1 1 1 1 1 1 1 1 1 1 ...
```

```
> str(IRIS)
'data.frame':	150 obs. of  5 variables:
Formal class 'ore.frame' [package "OREbase"] with 12 slots
  ..@ .Data    : list()
  ..@ dataQry  : Named chr "( select /*+ no_merge(t) */ \"Sepal.Length\" VAL001,\"Sepal.Wid
"( select /*+ no_merge(t) */  \"Sepal.Length\" VAL001,\"Sepal.Width\" VAL
002,\"Petal.Length\" VAL003,\"Petal.Width\" VAL004,\"Species\" VAL005 fro
m \"RQUSER\".\"IRIS\" t  )"
  .. ..$ name  : chr  "Sepal.Length" "Sepal.Width" "Petal.Length" "Petal.Width" ...
  .. ..$ Sclass: chr  "numeric" "numeric" "numeric" "numeric" ...
  ..@ sqlName  : chr
  ..@ sqlValue : chr  "\"Sepal.Length\"" "\"Sepal.Width\"" "\"Petal.Length\"" "\"Petal.Width
\"" ...
  ..@ sqlTable : chr "\"RQUSER\".\"IRIS\""
  ..@ sqlPred  : chr ""
  ..@ extRef   : list()
  ..@ names    : chr
  ..@ row.names: int
  ..@ .S3Class : chr "data.frame"
```

# Manipulating Data

## Column selection

```
df <- ONTIME_S[,c("YEAR","DEST","ARRDELAY")]
class(df)

head(df)
head(ONTIME_S[,c(1,4,23)])
head(ONTIME_S[,-(1:22)])
```

## Row selection

```
df1 <- df[df$DEST=="SFO",]
class(df1)

df2 <- df[df$DEST=="SFO",c(1,3)]
df3 <- df[df$DEST=="SFO" | df$DEST=="BOS",1:3]
head(df1)
head(df2)
head(df3)
```

```
> df <- ONTIME_S[,c("YEAR","DEST","ARRDELAY")]
> class(df)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
>
> head(df)
  YEAR DEST ARRDELAY
1 1987  MCI        0
2 1987  DEN        2
3 1987  HOU       -2
4 1987  SYR        0
5 1987  LAS       10
6 1987  DEN        2
> head(ONTIME_S[,c(1,4,23)])
    X MONTH2 TAXIIN
1 170    M10     NA
2 171    M10     NA
3 172    M10     NA
4 173    M10     NA
5 174    M10     NA
6 175    M10     NA
> head(ONTIME_S[,-(1:22)])
  TAXIIN TAXIOUT CANCELLED CANCELL
1     NA      NA         0
2     NA      NA         0
3     NA      NA         0
4     NA      NA         0
5     NA      NA         0
6     NA      NA         0
```

```
> df1 <- df[df$DEST=="SFO",]
> class(df1)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
>
> df2 <- df[df$DEST=="SFO",c(1,3)]
> df3 <- df[df$DEST=="SFO" | df$DEST=="BOS",1:3]
> head(df1)
  YEAR DEST ARRDELAY
1 1987  SFO       11
2 1987  SFO       -6
3 1987  SFO       -3
4 1987  SFO        6
5 1987  SFO       36
6 1987  SFO       30
> head(df2)
  YEAR ARRDELAY
1 1987       11
2 1987       -6
3 1987       -3
4 1987        6
5 1987       36
6 1987       30
> head(df3)
  YEAR DEST ARRDELAY
1 1987  SFO       11
2 1987  SFO       -6
3 1987  SFO       -3
4 1987  BOS        4
5 1987  SFO        6
6 1987  SFO       36
```

# Manipulating Data – SQL equivalent

## R

**Column selection**

```
df <- ONTIME_S[,c("YEAR","DEST","ARRDELAY")]
head(df)
head(ONTIME_S[,c(1,4,23)])
head(ONTIME_S[,-(1:22)])
```

**Row selection**

```
df1 <- df[df$DEST=="SFO",]
df2 <- df[df$DEST=="SFO",c(1,3)]
df3 <- df[df$DEST=="SFO" | df$DEST=="BOS",1:3]
```

**Benefits of OML4R transparency:**
In-database execution
Deferred execution
Leverage column indexes, partitioning,
query optimization, parallelism

## SQL

**Column selection**

```
create view df as
select YEAR, DEST, ARRDELAY
from   ONTIME_S;
```

-- cannot do column selection by number & exclusion in SQL

**Row selection**

```
create view df1 as
select * from df where DEST='SFO';

create view df2 as
select YEAR, ARRDELAY from df where DEST='SFO'

create view df3 as
select YEAR, DEST, ARRDELAY from df
where DEST='SFO' or DEST='BOS'
```

# merge

## Joining two tables (data frames)

```
df1 <- data.frame(x1=1:5, y1=letters[1:5])
df2 <- data.frame(x2=5:1,
y2=letters[11:15])
merge (df1, df2, by.x="x1", by.y="x2")

ore.drop(table="TEST_DF1")
ore.drop(table="TEST_DF2")

ore.create(df1, table="TEST_DF1")
ore.create(df2, table="TEST_DF2")
merge (TEST_DF1, TEST_DF2,
       by.x="x1", by.y="x2")
```

```
> df1 <- data.frame(x1=1:5, y1=letters[1:5])
> df2 <- data.frame(x2=5:1, y2=letters[11:15])
> merge (df1, df2, by.x="x1", by.y="x2")
  x1 y1 y2
1  1  a  o
2  2  b  n
3  3  c  m
4  4  d  l
5  5  e  k
>
> ore.drop(table="TEST_DF1")
> ore.drop(table="TEST_DF2")
>
> ore.create(df1, table="TEST_DF1")
> ore.create(df2, table="TEST_DF2")
> merge (TEST_DF1, TEST_DF2,
+        by.x="x1", by.y="x2")
  x1 y1 y2
1  5  e  k
2  4  d  l
3  3  c  m
4  2  b  n
5  1  a  o
```

# Formatting data – Base SAS “format” equivalent

```
diverted_fmt <- function (x) {
   ifelse(x=='0', 'Not Diverted',
   ifelse(x=='1', 'Diverted',''))
}

cancellationCode_fmt <- function(x) {
   ifelse(x=='A', 'A CODE',
   ifelse(x=='B', 'B CODE',
   ifelse(x=='C', 'C CODE',
   ifelse(x=='D', 'D CODE','NOT CANCELLED'))))
}

delayCategory_fmt <- function(x) {
   ifelse(x>200,'LARGE',
   ifelse(x>=30,'MEDIUM','SMALL'))
}

zscore <- function(x) {
   (x-mean(x,na.rm=TRUE))/sd(x,na.rm=TRUE)
}
```

```
x <- ONTIME_S
attach(x)

x$DIVERTED          <- diverted_fmt(DIVERTED)

x$CANCELLATIONCODE  <- cancellationCode_fmt(CANCELLATIONCODE)

x$ARRDELAY          <- delayCategory_fmt(ARRDELAY)

x$DEPDELAY          <- delayCategory_fmt(DEPDELAY)

x$DISTANCE_ZSCORE   <- zscore(DISTANCE)

detach(x)

head(x)
```

# Formatting data – Base SAS “format” equivalent

*Using transform ( )*

```
ONTIME <- transform(ONTIME_S,
      DIVERTED = ifelse(DIVERTED == 0, 'Not Diverted',
                 ifelse(DIVERTED == 1, 'Diverted', '')),

      CANCELLATIONCODE =
                 ifelse(CANCELLATIONCODE == 'A', 'A CODE',
                 ifelse(CANCELLATIONCODE == 'B', 'B CODE',
                 ifelse(CANCELLATIONCODE == 'C', 'C CODE',
                 ifelse(CANCELLATIONCODE == 'D', 'D CODE', 'NOT CANCELLED')))),

      ARRDELAY = ifelse(ARRDELAY > 200, 'LARGE',
                 ifelse(ARRDELAY >= 30, 'MEDIUM', 'SMALL')),

      DEPDELAY = ifelse(DEPDELAY > 200, 'LARGE',
                 ifelse(DEPDELAY >= 30, 'MEDIUM', 'SMALL')),

      DISTANCE_ZSCORE =(DISTANCE - mean(DISTANCE, na.rm=TRUE))/sd(DISTANCE, na.rm=TRUE))
head(ONTIME)
```

# Recoding data

*Using ore.recode ( )*

```
d <- ore.recode(ONTIME_S$DIVERTED, old=c(0,1),
                                   new=c('No','Yes'))
summary(as.ore.factor(d))
```

```
> d <- ore.recode(ONTIME_S$DIVERTED, old=c(0,1),
+                    new=c('No','Yes'))
> summary(as.ore.factor(d))
    No     Yes
219394     538
```

# Connecting to Oracle Database

Working with ore.frame *proxy* objects

# Establish a connection using ore.connect

```
if (!ore.is.connected())
  ore.connect(user="rquser", sid="orcl",
              host="localhost", password="rquser",
              all=TRUE)
ore.ls()
```

**ore.is.connected** returns TRUE if you're already connected to an Oracle Database

**ore.connect** parameters

- Port defaults to 1521
- "all" set to TRUE loads all tables from the schema into OML4R metadata and makes them available at the R command line as ore.frame objects

**ore.ls** lists all available tables by name

**ore.connect** does not support connecting to the database as `sys`

# ore.connect / ore.disconnect

Establish connection to ORE-enabled database

- Must precede all other calls to OML4R functionality
- Only one OML4R connection can be active at a time
- Calling ore.connect during an active OML4R connection results in disconnecting the current connection before starting the new connection

An OML4R connection implicitly terminates when its R session ends, but can disconnect explicitly

Argument **all**, if TRUE, call functions 'ore.sync' and 'ore.attach' using their default arguments

Argument **type**: either '"ORACLE"' (default) or '"HIVE"' for **OML4Spark** users. If '"HIVE"', all other connection parameters ignored and obtained from the system environment

```
if (!ore.is.connected())
  ore.connect("rquser", "orcl",
              "localhost", "rquser", all=TRUE)
ore.ls()
ore.disconnect()

ore.connect("rquser", host="localhost",
            password="rquser", service_name="ORCL",
            all=TRUE)

ore.connect(conn_string = "<wallet_connect_string>")

ore.connect(user="rquser",password="rquser",
            conn_string = "sales-server:1521:sales")

ore.connect(user="rquser",password="rquser",
            conn_string = "(DESCRIPTION=
   (ADDRESS=(PROTOCOL=tcp)(HOST=sales-server)(PORT=1521))
   (CONNECT_DATA= (SERVICE_NAME=sales.us.acme.com)))")

ore.connect(user="rquser",password="rquser",
            conn_string = "") # connect to local DB

ore.disconnect()
```

# Dataset: “ONTIME” Airline Data

On-time arrival data for non-stop domestic flights by major air carriers

Provides departure and arrival delays, origin and destination airports, flight numbers, scheduled and actual departure and arrival times, cancelled or diverted flights, taxi-out and taxi-in times, air time, and non-stop distance

- Full Data
  - 123M records
  - 22 years
  - 29 airlines
- Sample Data
  - ~220K records
  - ~10K / year
  - ONTIME_S

```
R> names(ONTIME_S)
 [1] "YEAR"              "MONTH"             "MONTH2"            "DAYOFMONTH"
 [5] "DAYOFMONTH2"       "DAYOFWEEK"         "DEPTIME"           "CRSDEPTIME"
 [9] "ARRTIME"           "CRSARRTIME"        "UNIQUECARRIER"     "FLIGHTNUM"
[13] "TAILNUM"           "ACTUALELAPSEDTIME" "CRSELAPSEDTIME"    "AIRTIME"
[17] "ARRDELAY"          "DEPDELAY"          "ORIGIN"            "DEST"
[21] "DISTANCE"          "TAXIIN"            "TAXIOUT"           "CANCELLED"
[25] "CANCELLATIONCODE"  "DIVERTED"
R>
R> dim(ONTIME_S)
[1] 219932     26
R>
R> str(ONTIME_S)
'data.frame':   219932 obs. of  26 variables:
Formal class 'ore.frame' [package "OREbase"] with 12 slots
  ..@ .Data    : list()
  ..@ dataQry  : Named chr "( select  \"YEAR\" VAL001,\"MONTH\" VAL002,\"MONTH2\" VAL003,\"DAYOFMONTH\" VAL
  .. ..- attr(*, "names")= chr "17_7"
  ..@ dataObj  : chr "17_7"
  ..@ desc     :'data.frame':   26 obs. of  2 variables:
  .. ..$ name  : chr  "YEAR" "MONTH" "MONTH2" "DAYOFMONTH" ...
  .. ..$ Sclass: chr  "numeric" "numeric" "factor" "numeric" ...
  ..@ sqlName  : chr
  ..@ sqlValue : chr  "\"YEAR\"" "\"MONTH\"" "\"MONTH2\"" "\"DAYOFMONTH\"" ...
  ..@ sqlTable : chr "\"RQUSER\".\"ONTIME_S\""
  ..@ sqlPred  : chr ""
  ..@ extRef   : list()
  ..@ names    : chr
  ..@ row.names: int
  ..@ .S3Class : chr "data.frame"
```

# ore.frame – Proxy object for database table

Examine the structure of the ore.frame object

- `str(ONTIME_S)`

```
> str(ONTIME_S)
'data.frame': 218210 obs. of  26 variables:
Formal class 'ore.frame' [package "OREbase"] with 12 slots
  ..@ .Data    : list()
  ..@ dataQry  : Named chr "( select  \"YEAR\" VAL001,\"MONTH\" VAL002,\"MONTH2\"
VAL003,\"DAYOFMONTH\" VAL004,\"DAYOFMONTH2\" VAL005,\"DAYOFWEEK\" VAL006,"| __truncated__
  .. ..- attr(*, "names")= chr "107_8"
  ..@ dataObj  : chr "107_8"
  ..@ desc     :'data.frame': 26 obs. of  2 variables:
  .. ..$ name  : chr  "YEAR" "MONTH" "MONTH2" "DAYOFMONTH" ...
  .. ..$ Sclass: chr  "numeric" "numeric" "factor" "numeric" ...
  ..@ sqlName  : chr
  ..@ sqlValue : chr  "\"YEAR\"" "\"MONTH\"" "\"MONTH2\"" "\"DAYOFMONTH\"" ...
  ..@ sqlTable : chr "\"STUDENT12\".\"ONTIME_S\""
  ..@ sqlPred  : chr ""
  ..@ extRef   : list()
  ..@ names    : chr
  ..@ row.names: int
  ..@ .S3Class : chr "data.frame"
```

# ore.frame – Proxy object for database table

Examine slot "dataQry" of the ore.frame object

- `ONTIME_S@dataQry`

```
> ONTIME_S@dataQry

107_8
"( select  \"YEAR\" VAL001,\"MONTH\" VAL002,\"MONTH2\" VAL003,\"DAYOFMONTH\" VAL004,\"DAYOFMONTH2\"
VAL005,\"DAYOFWEEK\" VAL006,\"DEPTIME\" VAL007,\"CRSDEPTIME\" VAL008,\"ARRTIME\"
VAL009,\"CRSARRTIME\" VAL010,\"UNIQUECARRIER\" VAL011,\"FLIGHTNUM\" VAL012,\"TAILNUM\"
VAL013,\"ACTUALELAPSEDTIME\" VAL014,\"CRSELAPSEDTIME\" VAL015,\"AIRTIME\" VAL016,\"ARRDELAY\"
VAL017,\"DEPDELAY\" VAL018,\"ORIGIN\" VAL019,\"DEST\" VAL020,\"DISTANCE\" VAL021,\"TAXIIN\"
VAL022,\"TAXIOUT\" VAL023,\"CANCELLED\" VAL024,\"CANCELLATIONCODE\" VAL025,\"DIVERTED\" VAL026 from
\"STUDENT12\".\"ONTIME_S\"  )"
```

# ore.frame – Proxy object for database table

Examine slot “desc” of the ore.frame object

- `ONTIME_S@desc`

```
> ONTIME_S@desc
                  name  Sclass
1                 YEAR numeric
2                MONTH numeric
3               MONTH2  factor
4           DAYOFMONTH numeric
5          DAYOFMONTH2  factor
6            DAYOFWEEK numeric
7              DEPTIME numeric
8           CRSDEPTIME numeric
9              ARRTIME numeric
10          CRSARRTIME numeric
11       UNIQUECARRIER  factor
12           FLIGHTNUM numeric
13             TAILNUM  factor
14   ACTUALELAPSEDTIME numeric
15      CRSELAPSEDTIME numeric
16             AIRTIME numeric
17            ARRDELAY numeric
18            DEPDELAY numeric
19              ORIGIN  factor
20                DEST  factor
21            DISTANCE numeric
22              TAXIIN numeric
23             TAXIOUT numeric
24           CANCELLED numeric
25    CANCELLATIONCODE  factor
26            DIVERTED  factor
```

# OML4R functions for interacting with database data

Synchronize OML4R proxy objects in R with tables/views available in database, on a per schema basis

Create ore.frame object directly from query without having to explicitly create a DB view

Store R object in database as temporary object, returns handle to object. Data frame, matrix, and vector to table, list/model/others to serialized object

Returns TRUE if named table or view exists in schema

```
ore.sync()
ore.sync("RQUSER")
ore.sync(table=c("ONTIME_S", "NARROW"))
ore.sync("RQUSER", table=c("ONTIME_S", "NARROW"))
ore.sync(query = c("QUERY1" = "select 0 X, 1 Y from dual",
                   "QUERY2" = "select 1 X, 0 Y from dual"))
ore.ls()
v <- ore.push(c(1,2,3,4,5))
class(v)
df <- ore.push(data.frame(a=1:5, b=2:6))
class(df)

ore.exists("ONTIME_S", "RQUSER")
```

**Caveat for ore.sync:**
Data types long, long raw, UDTs, and reference types not supported
When encountered, warning issued and table not available, e.g., via ore.ls()

# OML4R functions for interacting with database data

Make database objects visible in R for named schema. Can place corresponding environment in specific position in env path

List the objects available in OML4R environment mapped to database schema. all.names=FALSE excludes names starting with a '.'

Obtain object to named table/view in schema

Remove schema's environment from the object search path

Remove table or view from schema's R environment

```
ore.attach("RQUSER")
ore.attach("RQUSER", pos=2)
search()

ore.ls()
ore.ls("RQUSER")
ore.ls("RQUSER",all.names=TRUE)
ore.ls("RQUSER",all.names=TRUE, pattern= "NAR")

t <- ore.get("ONTIME_S","RQUSER")
dim(t)

ore.detach("RQUSER")

ore.rm("ONTIME_S")
ore.exists("ONTIME_S", "RQUSER")
ore.sync()
ore.exists("ONTIME_S", "RQUSER")
ore.rm(c("ONTIME_S","NARROW"), "RQUSER")
ore.sync()
ore.attach()
```

# Creating and dropping tables

**Execute SQL or PL/SQL without return value**

```
ore.exec("create table F2 as select * from ONTIME_S")
```

**Create a database table from a data.frame or ore.frame. Create a view from an ore.frame**

```
ore.create(ONTIME_S, table = "NEW_ONTIME_S")
ore.create(ONTIME_S, view = "NEW_ONTIME_S_VIEW")
```

**Drop table or view in database**

```
ore.drop(table="F2")
ore.drop(table="NEW_ONTIME_S")
ore.drop(view="NEW_ONTIME_S_VIEW")
```

**Create a data.frame and then create a database table from it, then clean up**

```
df <- data.frame(A=1:26, B=letters[1:26])
class(df)
ore.create(df,table="TEST_DF")
ore.ls(pattern="TEST_DF")
class(TEST_DF)
head(TEST_DF)
ore.drop(table="TEST_DF")
```

**Load data (pull) from database**

```
ontime <- ore.pull(ONTIME_S)
class(ONTIME_S)
class(ontime)
```

# OREbase package

as.ore*

ore.vector

ore.character

ore.factor

ore.frame

ore.matrix

# Convert R type to OML4R type

as.ore.character
as.ore.numeric
as.ore.vector
as.ore.matrix
as.ore.frame
as.ore

```
df <- data.frame(A=1:26, B=letters[1:26])
dim(df)
class(df)
ore.f <- as.ore(df)
class(ore.f)
dim(ore.f)
head(ore.f)
```

```
> df <- data.frame(A=1:26, B=letters[1:26])
> dim(df)
[1] 26  2
> class(df)
[1] "data.frame"
> ore.f <- as.ore(df)
> class(ore.f)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
> dim(ore.f)
[1] 26  2
> head(ore.f)
  A B
1 1 a
2 2 b
3 3 c
4 4 d
5 5 e
6 6 f
```

# ore.vector functions

show
length
c
is.vector
as.vector
[
head
tail
I
compare
==, >, <, !=, <=, >=
is.na
cut
%in%
unique
split
sort
rank
order
table
paste
interaction
sapply
tapply
by

# cut - binning

Divides the range of 'x' into intervals

Codes the values in 'x' according to which interval they fall

Leftmost interval corresponds to level one, the next leftmost to level two, etc.

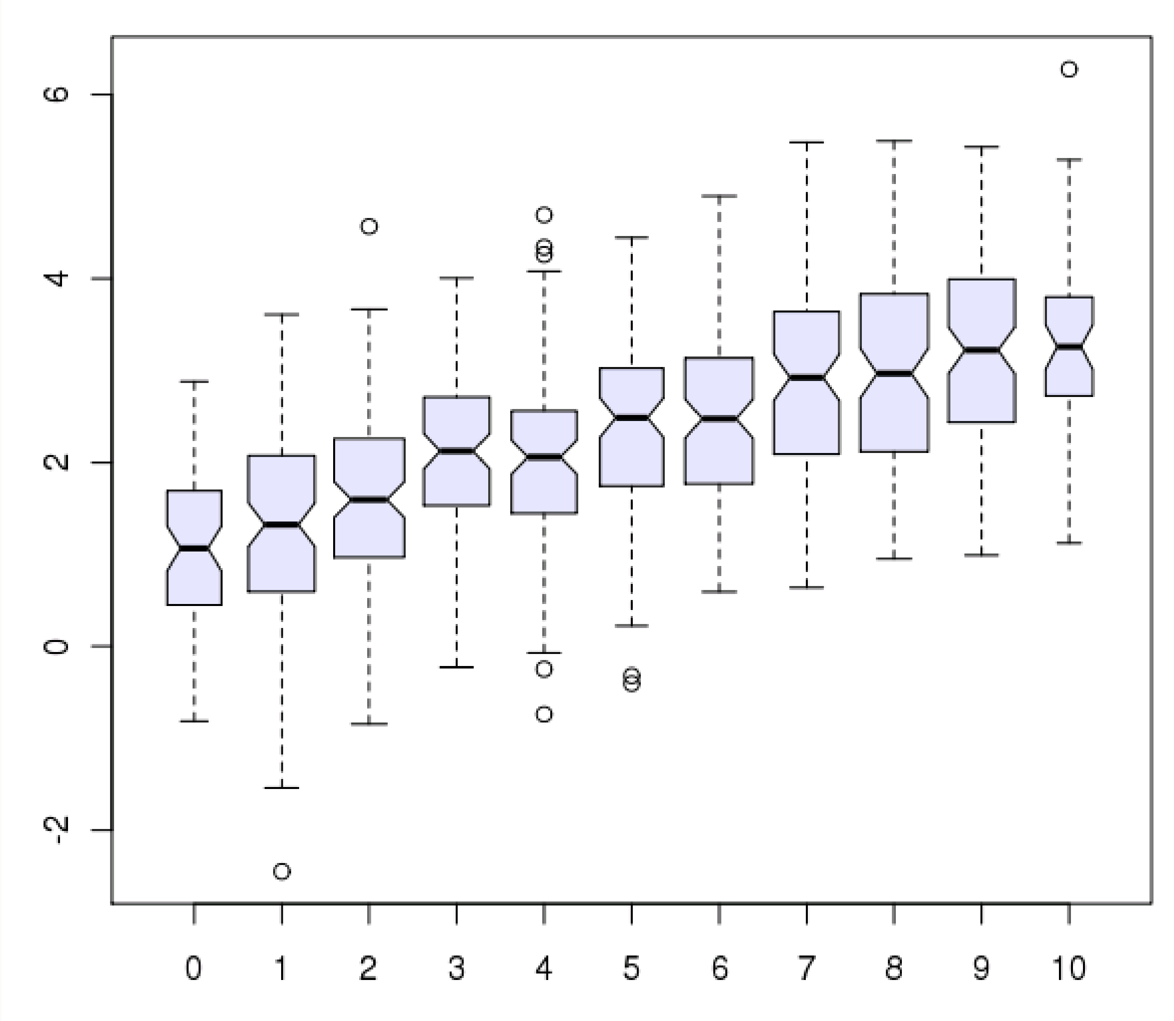
```
x <- ONTIME_S
x$ARRDELAY_BINNED = cut(x$ARRDELAY,
                        breaks=c(-1000,-100,-50,-10,0,10,50,100,1000))
class(x$ARRDELAY_BINNED)   # [1] "ore.factor”

# OR

x$ARRDELAY_BINNED = cut(x$ARRDELAY,
                        breaks=c(-1000,-100,-50,-10,0,10,50,100,1000),
                        labels=FALSE)
class(x$ARRDELAY_BINNED)   # [1] "ore.integer”

# EXPLICITLY convert this column to a factor if labels = FALSE

# Include x$DISTANE_BINNED into an ore.glm, ore.lm,
#    or ore.neural formula,  it’s treated as categorical
x$DISTANCE_BINNED = cut(x$DISTANCE,
                        breaks=c(-1000,-100,-50,-10,0,10,50,100,1000))
fit = ore.glm(data=x,
                        formula=CANCELLED ~ DISTANCE_BINNED,
                        family=binomial(), trace=2)
```

# split, sapply

split() divides the data in the vector x into the groups defined by the factor g

The result is a list with elements corresponding to the partitioned data

```
n <- 10; nn <- 100
g <- factor(round(n * runif(n * nn)))
x <- rnorm(n * nn) + sqrt(as.numeric(g))
X <- as.ore(x)
G <- as.ore(g)

XG <- split(X, G)

boxplot(XG, col = "lavender", notch =
TRUE, varwidth = TRUE)

sapply(XG, length)
sapply(XG, mean)
```



```
R> sapply(XG, length)
  0   1   2   3   4   5   6   7   8   9  10
 46 110  94 106  96 102  96 110  81 108  51
R> sapply(XG, mean)
       0        1        2        3        4        5        6        7        8        9       10
1.100634 1.488460 1.770047 2.011026 2.205655 2.461026 2.822435 2.756720 3.069607 3.244167 3.481981
```

# split, sapply

split() divides the data in the vector x into the groups defined by the factor g

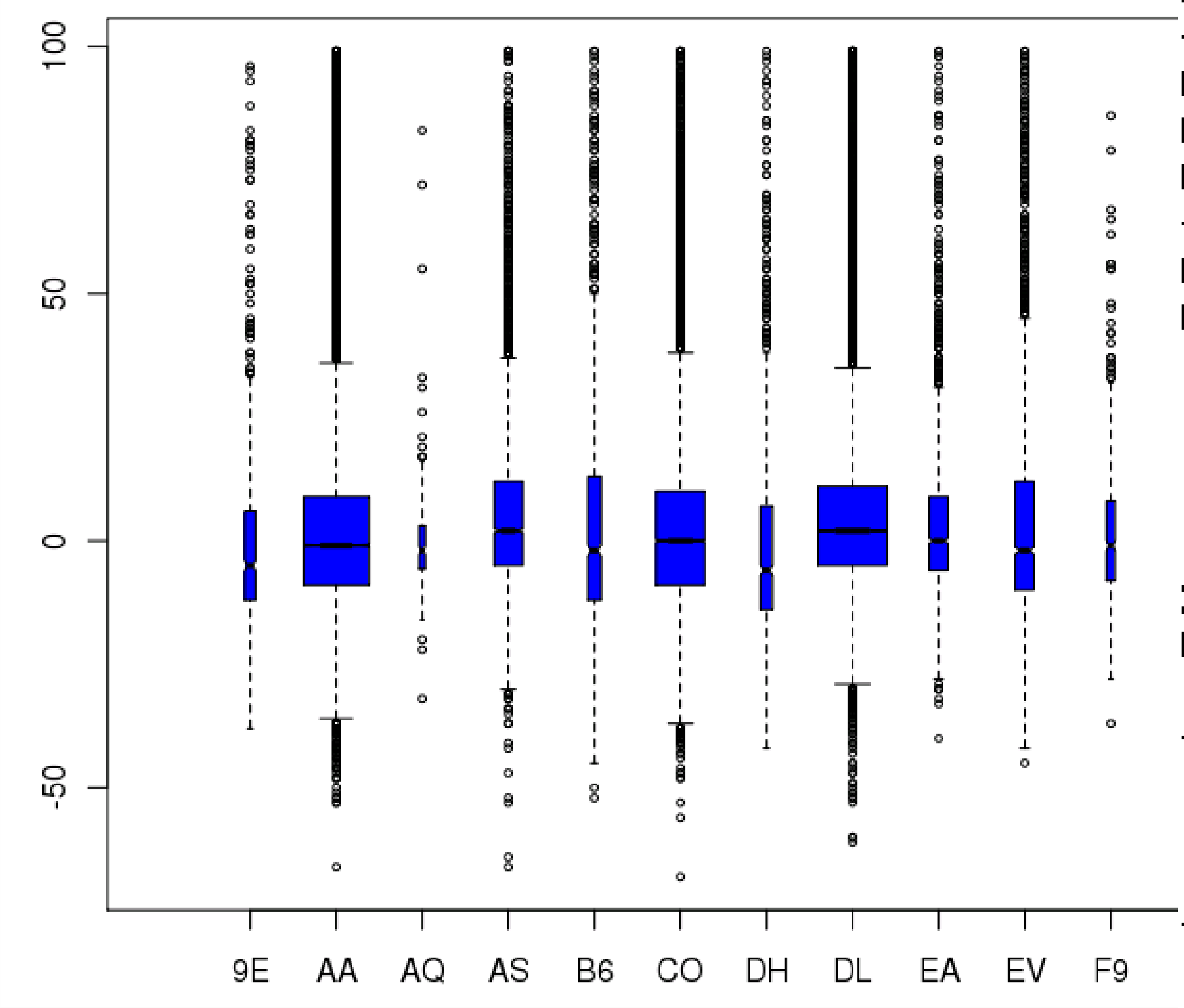
The result is a list with elements corresponding to the partitioned data

sapply() invokes the function on the list and returns a vector or matrix of the same length

sapply is a user-friendly version and wrapper of lapply by default returning a vector or matrix

```
dat <- ONTIME_S[ONTIME_S$ARRDELAY < 100 &
                ONTIME_S$ARRDELAY > -100,]
ad <- with(dat,split(ARRDELAY, UNIQUECARRIER))

boxplot(ad, col = "blue", notch = TRUE, cex=0.5,
        varwidth = TRUE)

sapply(ad, length)
sapply(ad, mean, na.rm=TRUE)
```

# split, sapply results




```
ORE> dat <- ONTIME_S[ONTIME_S$ARRDELAY < 100 &
+                    ONTIME_S$ARRDELAY > -100,]
ORE> ad <- with(dat,split(ARRDELAY, UNIQUECARRIER))
ORE>
ORE> boxplot(ad, col = "blue", notch = TRUE, cex=0.5,
+          varwidth = TRUE)
ORE>
ORE> sapply(ad, length)
   9E    AA    AQ    AS    B6    CO    DH    DL    EA    EV    F9    FL    HA
  695 26494   226  4990  1129 14726   968 29327  2194  2192   477  1677   352
   HP ML(1)    MQ    NW    OH    OO PA(1)    PI    PS    TW    TZ    UA    US
 6608   131  5562 17917  1957  4112   710  2272   399  7217   284 23171 24818
   WN    XE    YV
26734  3093  1075
ORE> sapply(ad, mean, na.rm=TRUE)
         9E          AA          AQ          AS          B6          CO
-0.27625899  3.22676832  0.06637168  5.85931864  4.12754650  3.27930191
         DH          DL          EA          EV          F9          FL
 0.21797521  5.46458895  4.11394713  4.58257299  1.92872117  5.18306500
         HA          HP       ML(1)          MQ          NW          OH
-2.63636364  5.44718523  3.19083969  3.77220424  2.91309929  3.25958099
         OO       PA(1)          PI          PS          TW          TZ
 2.06104086  3.35070423  8.14788732 11.06015038  4.62006374  0.77112676
         UA          US          WN          XE          YV
 4.81908420  4.37001370  4.01911424  3.45328160  4.80093023
```

# table

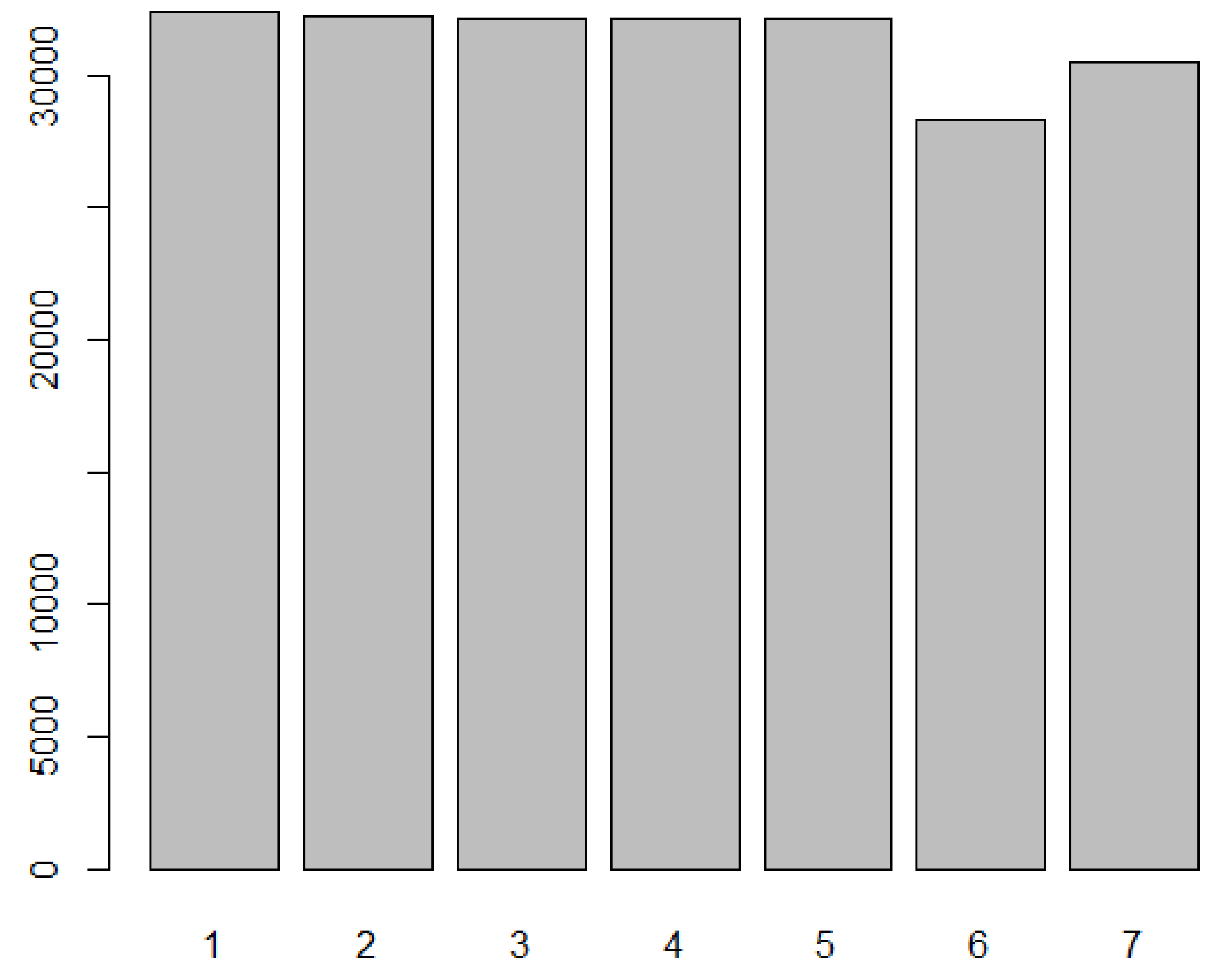
table() uses the cross-classifying factors to build a contingency table of the counts at each combination of factor levels

The result is an object of type “table”

```
(t <- table(ONTIME_S$DAYOFWEEK))
class(t)
barplot(t)

table(ONTIME_S$DAYOFWEEK, ONTIME_S$CANCELLED)

with (ONTIME_S,
      table(DAYOFWEEK,CANCELLED,DIVERTED))
```

# table results

```
ORE> (t <- table(ONTIME_S$DAYOFWEEK))

    1     2     3     4     5     6     7
32383 32254 32181 32165 32138 28335 30476
ORE> class(t)
[1] "table"
ORE> plot(t)
ORE>
ORE> table(ONTIME_S$DAYOFWEEK, ONTIME_S$CANCELLED)

        0     1
  1 31783   600
  2 31582   672
  3 31579   602
  4 31610   555
  5 31603   535
  6 27868   467
  7 30047   429
```




```
ORE> with (ONTIME_S, table(DAYOFWEEK,CANCELLED,DIVERTED))
, , DIVERTED = 0

         CANCELLED
DAYOFWEEK     0     1
        1 31706   600
        2 31514   672
        3 31494   602
        4 31519   555
        5 31516   535
        6 27807   467
        7 29978   429

, , DIVERTED = 1

         CANCELLED
DAYOFWEEK     0     1
        1    77     0
        2    68     0
        3    85     0
        4    91     0
        5    87     0
        6    61     0
        7    69     0
```

# ore.character functions

nchar
tolower
toupper
casefold
chartr
sub
gsub
substr

```
x <- as.ore.character("MiXeD cAsE 123")

chartr("iXs", "why", x)

chartr("a-cX", "D-Fw", x)
```

```
ORE> x <- as.ore.character("MiXeD cAsE 123")
ORE>
ORE> chartr("iXs", "why", x)
[1] "MwheD cAyE 123"
ORE>
ORE> chartr("a-cX", "D-Fw", x)
[1] "MiweD FAsE 123"
```

# ore.factor functions

levels

is.factor

as.factor

summary

```
levels(ONTIME_S$CANCELLATIONCODE)
[1] "A" "B" "C" "D"


summary(ONTIME_S$CANCELLATIONCODE)
      A       B       C       D   NA's
    421     378     172       2 218959
```

# ore.frame functions

- show
- attach
- [
- $
- [[
- head
- tail
- length
- nrow
- ncol
- dim
- names

- colnames
- dimnames
- merge
- as.list
- unlist
- summary
- rbind
- cbind
- data.frame
- as.data.frame
- as.env

- eval
- subset
- with
- within
- transform
- arith
  Unary: +, -
  Binary: +, -, *, ^, %%, %/%, /
- compare
  ==, >, <, !=, <=, >=
- !
- xor

# ore.frame functions

is.na

is.finite

is.nan

is.infinite

Math
 abs, sign, sqrt, ceiling, floor, trunc, cummax, cummin, cumprod, cumsum, exp, expm1, log, log10, log2, log1p, cos, cosh, sin, sinh, tan, tanh, acos, acosh, asin, asinh, atan, atanh, gamma, lgamma, digamma, trigamma

Summary
 max, min, range, prod, sum, any, all

rowSums

colSums

rowMeans

colMeans

scale

Interaction

split

unique

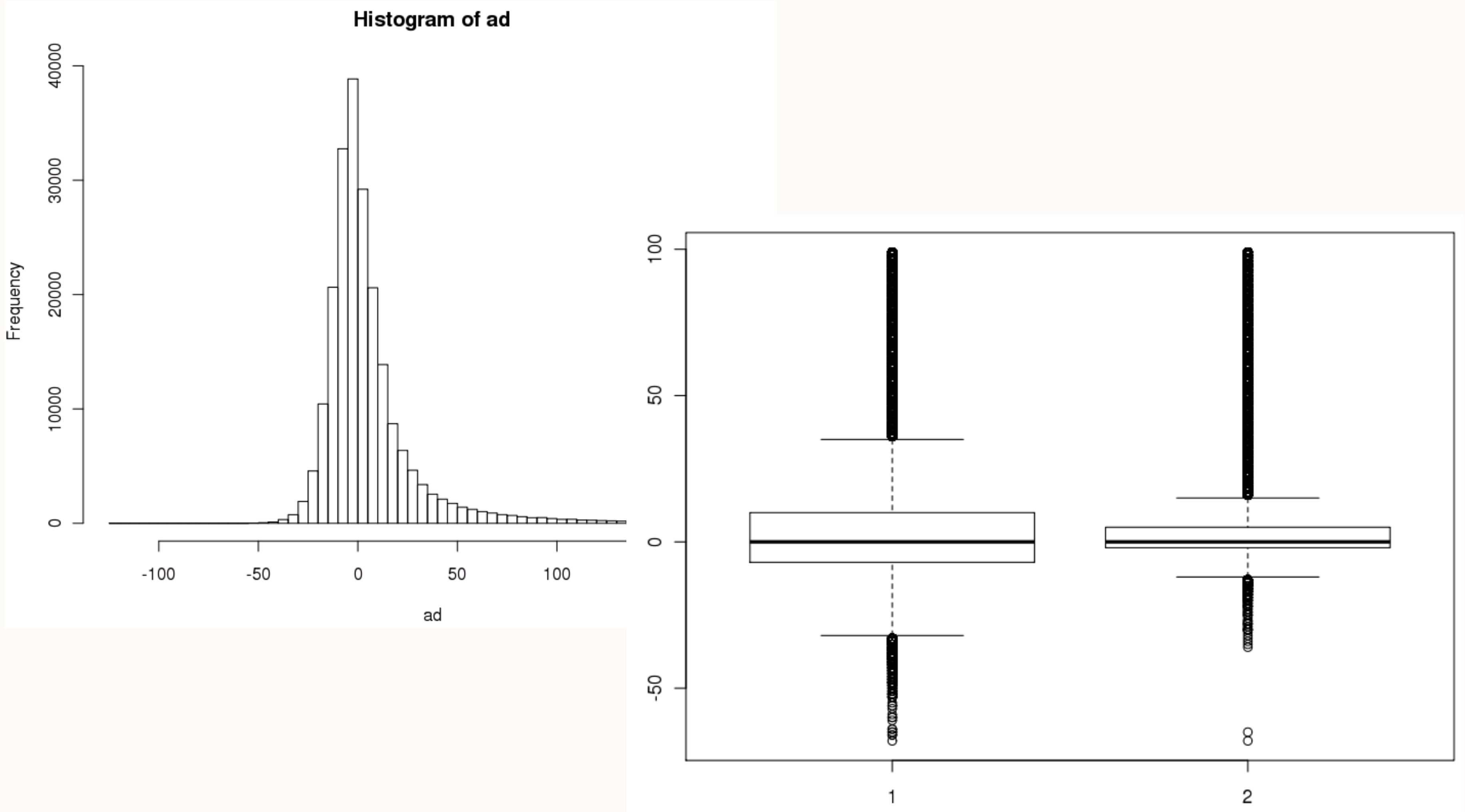
by

princomp

# subset()

```
ad <- ONTIME_S$ARRDELAY
ad <- subset(ad,ad<200 & ad>-200)

hist(ad,breaks=100)

addd <- ONTIME_S[,c("ARRDELAY",
"DEPDELAY")]
addd <- subset(addd,ARRDELAY < 100 &
                    ARRDELAY > -100 &
                    DEPDELAY < 100)
boxplot(addd$ARRDELAY, addd$DEPDELAY)
```

Return subsets of vectors, matrices or data frames which meet conditions.



# scale

centers and/or scales the columns of a numeric ore.frame

Also referred to as "normalizing"

```
X <- ONTIME_S[,c("ARRDELAY", "DEPDELAY")]

centered.X <- scale(X, scale=FALSE)
head(centered.X)

scaled.X <- scale(X, scale=TRUE)
head(scaled.X)
```

```
R> require(stats)
R> X <- ONTIME_S[,c("ARRDELAY", "DEPDELAY")]
R>
R> centered.X <- scale(X, scale=FALSE)
R> head(centered.X)
     ARRDELAY  DEPDELAY
0 -3.05837594 -8.041657
1 -1.05837594 -8.041657
2 -0.05837594 -8.041657
3  1.94162406  1.958343
4 -7.05837594 -6.041657
5 -3.05837594 -8.041657
R>
R> scaled.X <- scale(X, scale=TRUE)
R> head(scaled.X)
      ARRDELAY     DEPDELAY
0 -0.100734629 -0.28947796
1 -0.034860040 -0.28947796
2 -0.001922746 -0.28947796
3  0.063951844  0.07049505
```

# princomp

Performs a principal component analysis on the given numeric ore.frame and returns the results as an object of class 'princomp'

```
USA <- ore.push (USArrests)
princomp(USA, cor = TRUE)
```

```
R> USA <- ore.push (USArrests)
R> princomp(USA, cor = TRUE)
Call:
princomp(USA, cor = TRUE)

Standard deviations:
   Comp.1    Comp.2    Comp.3    Comp.4
1.5748783 0.9948694 0.5971291 0.4164494

 4  variables and  50 observations.
```

# transform

Applies transformations to a data.frame / ore.frame

```
X <- ONTIME_S[,c("ARRDELAY", "DEPDELAY")]


X <-
transform(X,scale.ARRDELAY=scale(ARRDELAY),
              scale.DEPDELAY=scale(DEPDELAY))
head(X)
```

```
> X <- ONTIME_S[,c("ARRDELAY", "DEPDELAY")]
>
> X <- transform(X,scale.ARRDELAY=scale(ARRDELAY),
+                scale.DEPDELAY=scale(DEPDELAY))
> head(X)
  ARRDELAY DEPDELAY scale.ARRDELAY scale.DEPDELAY
1        4        0   -0.100734629    -0.28947796
2        6        0   -0.034860040    -0.28947796
3        7        0   -0.001922746    -0.28947796
4        9       10    0.063951844     0.07049505
5        0        2   -0.232483808    -0.21748336
6        4        0   -0.100734629    -0.28947796
```

# ore.matrix functions

- show
- is.matrix
- as.matrix
- nrow
- ncol
- dim
- rownames
- colnames
- dimnames
- t
- tabulate

- Arith
  Unary: +, -
  Binary: +, -, *, ^, %%, %/%, /
- Math
  abs, sign, sqrt, ceiling, floor, trunc, cummax, cummin, cumprod, cumsum, exp, expm1, log, log10, log2, log1p, cos, cosh, sin, sinh, tan, tanh, acos, acosh, asin, asinh, atan, atanh, gamma, lgamma, digamma, trigamma
- Summary
  max, min, range, prod, sum, any, all
- mean

- Bessel
  bessel I, K, J, Y
- %*%
- crossprod
- tcrossprod
- solve
- backsolve
- forwardsolve

# Matrix multiplication %*%

%*% - multiplies two matrices, if they are conformable

```
x <- 1:4
y <- diag(x)
z <- matrix(1:12, ncol = 3, nrow = 4)
X <- ore.push(x); Y <- ore.push(y); Z <-
ore.push(z)
X %*% Z
Y %*% X
X %*% Z
Y %*% Z
```

```
R> Y
     [,1] [,2] [,3] [,4]
[1,]    1    0    0    0
[2,]    0    2    0    0
[3,]    0    0    3    0
[4,]    0    0    0    4
R> Z
     [,1] [,2] [,3]
[1,]    1    5    9
[2,]    2    6   10
[3,]    3    7   11
[4,]    4    8   12
R>
R> Y %*% Z
     [,1] [,2] [,3]
[1,]    1    5    9
[2,]    4   12   20
[3,]    9   21   33
[4,]   16   32   48
```

# solve

solves the equation a %*% x = b for x, where b can be either a vector or a matrix

```
hilbert <- function(n) {
      i <- 1:n
      1 / outer(i - 1, i, "+")
   }
h8 <- hilbert(8); h8
sh8 <- solve(h8)
round(sh8 %*% h8, 3)

H8 <- ore.push(h8)
SH8 <- solve(H8)
round(SH8 %*% H8, 3)
# Same result...
```

```
R> hilbert <- function(n) { i <- 1:n; 1 / outer(i - 1, i, "+") }
R> h8 <- hilbert(8); h8
          [,1]      [,2]      [,3]       [,4]       [,5]       [,6]       [,7]       [,8]
[1,] 1.0000000 0.5000000 0.3333333 0.25000000 0.20000000 0.16666667 0.14285714 0.12500000
[2,] 0.5000000 0.3333333 0.2500000 0.20000000 0.16666667 0.14285714 0.12500000 0.11111111
[3,] 0.3333333 0.2500000 0.2000000 0.16666667 0.14285714 0.12500000 0.11111111 0.10000000
[4,] 0.2500000 0.2000000 0.1666667 0.14285714 0.12500000 0.11111111 0.10000000 0.09090909
[5,] 0.2000000 0.1666667 0.1428571 0.12500000 0.11111111 0.10000000 0.09090909 0.08333333
[6,] 0.1666667 0.1428571 0.1250000 0.11111111 0.10000000 0.09090909 0.08333333 0.07692308
[7,] 0.1428571 0.1250000 0.1111111 0.10000000 0.09090909 0.08333333 0.07692308 0.07142857
[8,] 0.1250000 0.1111111 0.1000000 0.09090909 0.08333333 0.07692308 0.07142857 0.06666667
R> sh8 <- solve(h8)
R> round(sh8 %*% h8, 3)
     [,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
[1,]    1    0    0    0    0    0    0    0
[2,]    0    1    0    0    0    0    0    0
[3,]    0    0    1    0    0    0    0    0
[4,]    0    0    0    1    0    0    0    0
[5,]    0    0    0    0    1    0    0    0
[6,]    0    0    0    0    0    1    0    0
[7,]    0    0    0    0    0    0    1    0
[8,]    0    0    0    0    0    0    0    1
```

# OREgraphics package functions

arrows
boxplot
boxplot.stats
cdplot
coplot
hist
identify
lines
matplot
pairs
plot

points
polygon
polypath
rug
segments
smoothScatter
sunflowerplot
symbols
text
xspline
xy.coords

# OREstat package function

- IQR
- aggregate
- binom.test
- chisq.test
- cor
- cov
- fitdistr
- ks.test
- mad
- median
- model.frame
- model.matrix
- aa.omit
- quantile
- reorder
- rnorm
- sd
- t.test
- terms
- var
- var.test
- wilcox.test

# Invoke in-database aggregation function

```
aggdata <- aggregate(ONTIME_S$DEST,
                     by = list(ONTIME_S$DEST),
                     FUN = length)
class(aggdata)
head(aggdata)
```

```
R> aggdata <- aggregate(ONTIME_S$DEST,
+                       by = list(ONTIME_S$DEST),
+                       FUN = length)
R> class(aggdata)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> head(aggdata)
  Group.1    x
0     ABE  237
1     ABI   34
2     ABQ 1357
3     ABY   10
4     ACK    3
5     ACT   33
```

Source data is an ore.frame ONTIME_S, which resides in Oracle Database

Overloaded aggregate() function accepts ORE frames

aggregate() transparently switches between code that works with standard R data.frame and ore.frame objects

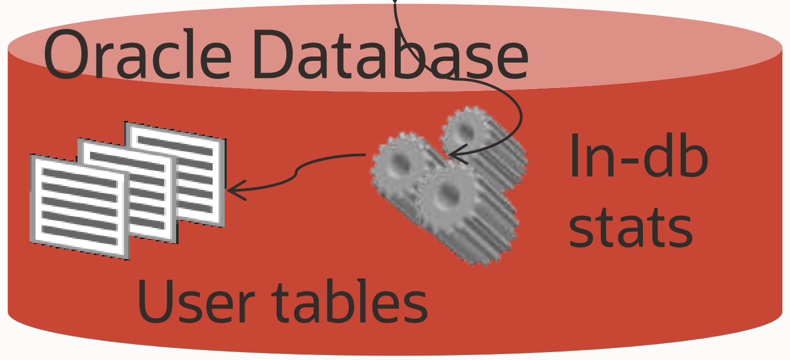
Returns an ore.frame

Client R Engine

Transparency Layer

OML4R

```
select DEST, count(*)
from ONTIME_S
group by DEST
```



# ks.test – Kolmgorov-Smirnov test

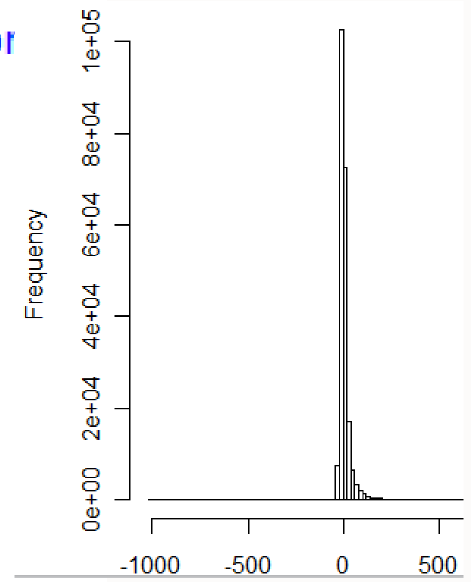
Tests for the equality of continuous (numeric) vector probability distributions

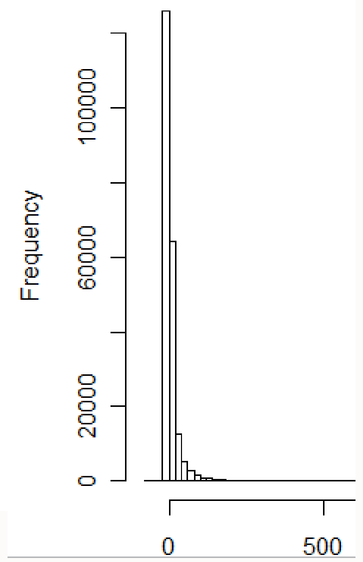
Compares...

- a sample with a reference probability distribution (one-sample KS test)
- Two samples (two-sample KS test)

```
x <- ore.push(rnorm(500))
y <- ore.push(runif(300))
# Do x and y come from the same distribution?
ks.test(x, x)
ks.test(x, y)

x <- ONTIME_S$ARRDELAY
y <- ONTIME_S$DEPDELAY
# Do x and y come from the same distribution?
ks.test(x, y)
```

```
> x <- ore.push(rnorm(500))
> y <- ore.push(runif(300))
> # Do x and y come from the same distributio
> ks.test(x, y)

 Two-sample Kolmogorov-Smirnov test

data:  x and y
D = 0.494, p-value < 2.2e-16
alternative hypothesis: two-sided

>
>
> x <- ONTIME_S$ARRDELAY
> y <- ONTIME_S$DEPDELAY
> # Do x and y come from the same distribution?
> ks.test(x, y)

 Two-sample Kolmogorov-Smirnov test

data:  x and y
D = 0.2363, p-value < 2.2e-16
alternative hypothesis: two-sided
```



# OREeda package functions

*exploratory data analysis*

ore.corr

ore.crosstab

ore.freq

ore.lm

ore.rank

ore.sort

ore.summary

ore.univariate

# Solve problems involving ONTIME data set

# Investigation Questions on ONTIME_S

Are some airports more prone to delays than others?

Are some days of the week likely to see fewer delays than others?

- Are these differences significant?

How do arrival delay distributions differ for the best and worst 3 airlines compared to the industry?

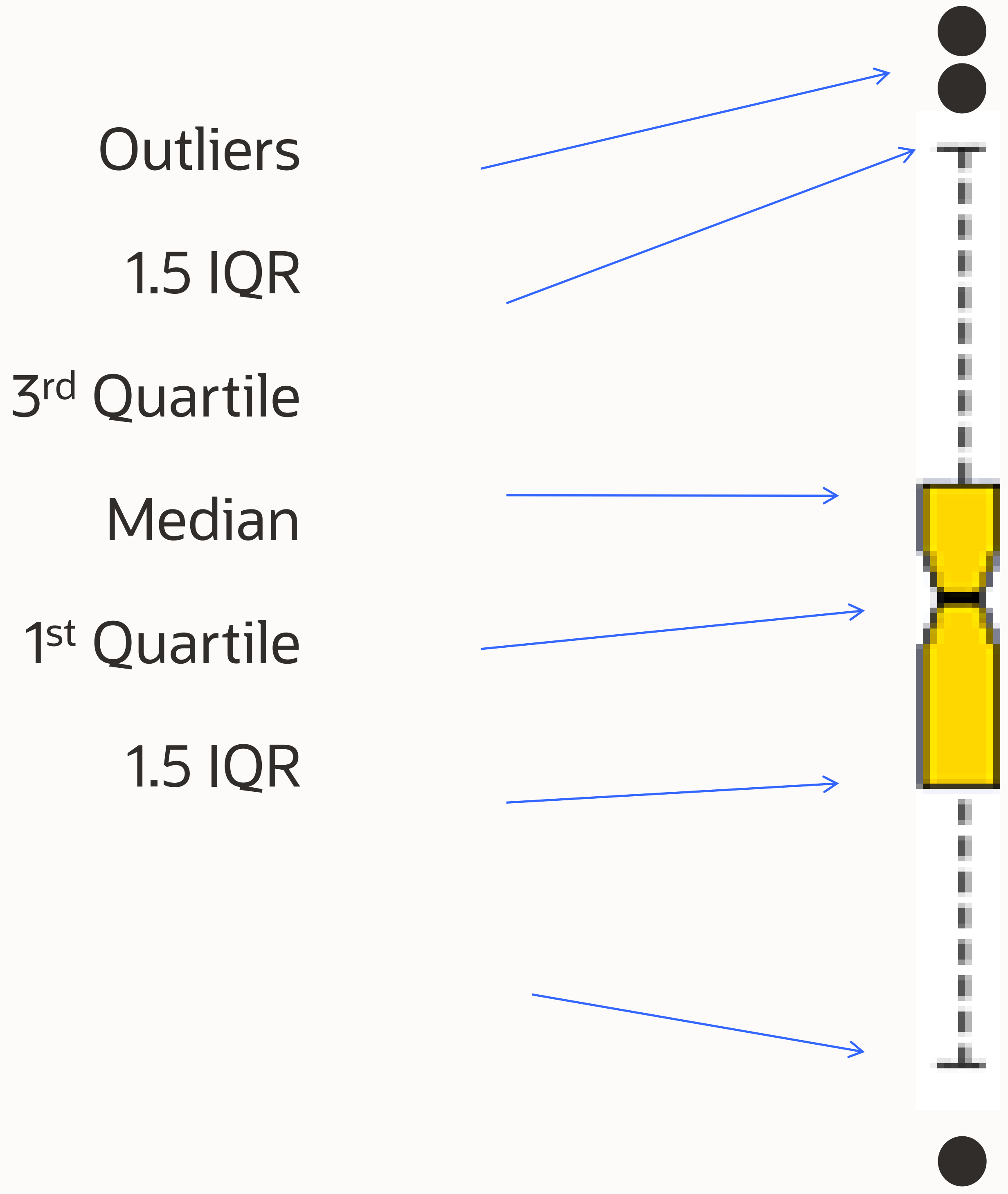
- Are there significant differences among airlines?

For American Airlines, how has the distribution of delays for departures and arrivals evolved over time?

How do average annual arrival delays compare across select airlines?

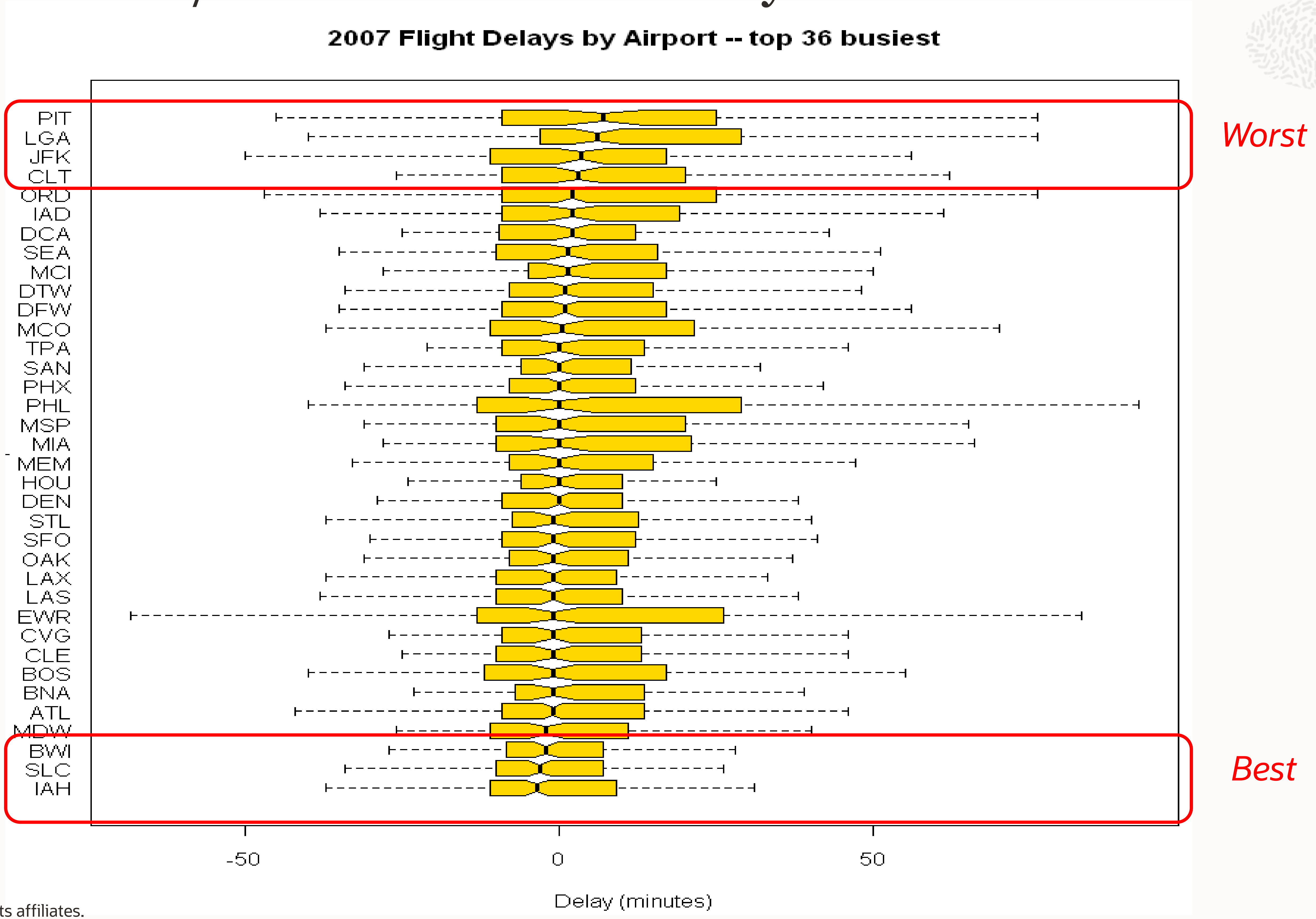
- What is the underlying trend for each airline?

# Interpreting a Box Plot




- Facilitates comparison among multiple variables
- Limited number of quantities summarize each distribution
- *Interquartile range* measures spread of distribution (middle 50% of data)
- Median position indicates *skew*
- *Notch* gives roughly 95% confidence interval for the median

# Of the 36 busiest airports, which are the best/worst for Arrival Delay?

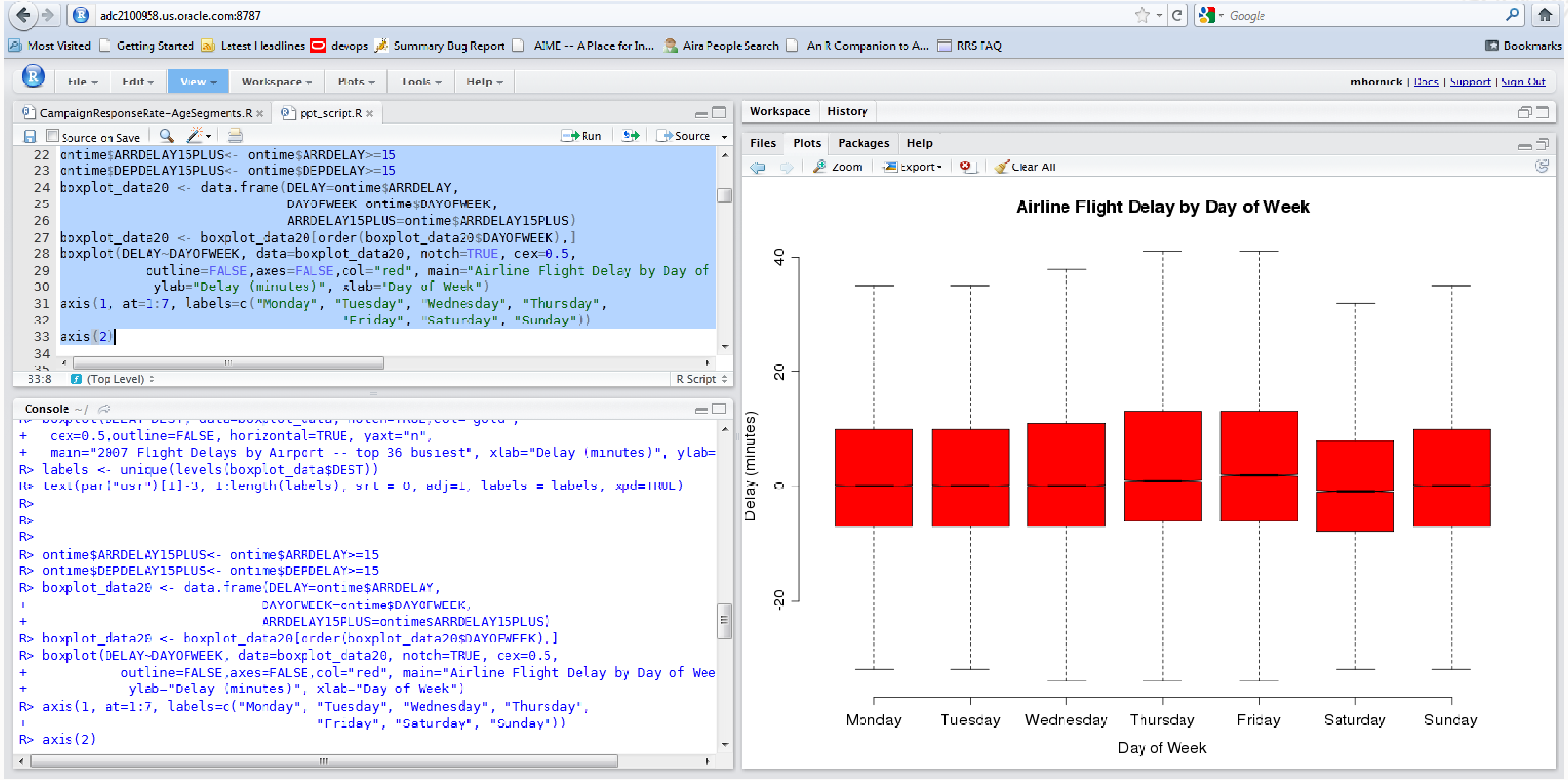


# Of the 36 busiest airports, which are the best/worst for Arrival Delay?

*Run one line at a time and view the result*

```
ontime <- ONTIME_S
aggdata <- aggregate(ontime$DEST, by = list(ontime$DEST), FUN = length)
minx <- min(head(sort(aggdata$x, decreasing = TRUE), 36))
busiest_airports <- aggdata$Group.1[aggdata$x >= minx, drop = TRUE]
delay <- ontime$ARRDELAY[ontime$DEST %in% busiest_airports & ontime$YEAR == 2007]
dest <- ontime$DEST[ontime$DEST %in% busiest_airports & ontime$YEAR == 2007, drop =
TRUE]
dest <- reorder(dest, delay, FUN = median, na.rm = TRUE)
bd <- split(delay, dest)
boxplot(bd, notch = TRUE, col = "gold", cex = 0.5,
            outline = FALSE, horizontal = TRUE, yaxt = "n",
            main = "2007 Flight Delays by Airport -- top 36 busiest",
            ylab = "Delay (minutes)", xlab = "Airport")
labels <- levels(dest)
text(par("usr")[1] - 3, 1:length(labels), srt = 0, adj = 1,
     labels = labels, xpd = TRUE, cex = 0.75)
```

# Which days were the worst to fly for delays over the past 22 years?



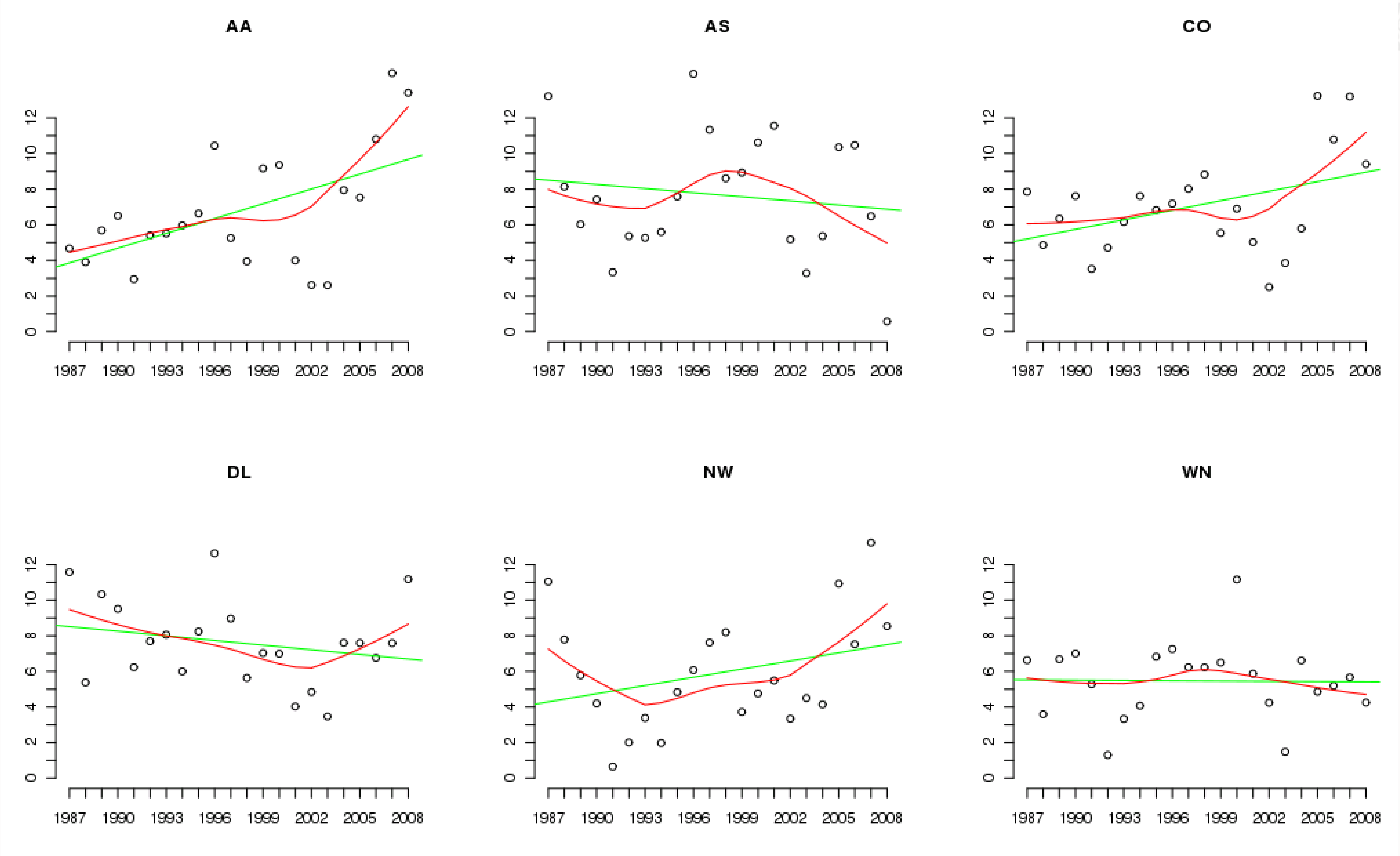
# Which days were the worst to fly for delays over the past 22 years?

*Run one line at a time and view the result*

```
ontime <- ONTIME_S
delay <- ontime$ARRDELAY
dayofweek <- ontime$DAYOFWEEK
bd <- split(delay, dayofweek)
boxplot(bd, notch = TRUE, col = "red", cex = 0.5,
        outline = FALSE, axes = FALSE,
        main = "Airline Flight Delay by Day of Week",
        ylab = "Delay (minutes)", xlab = "Day of Week")
axis(1, at=1:7, labels=c("Monday", "Tuesday", "Wednesday", "Thursday",
                         "Friday", "Saturday", "Sunday"))
axis(2)
```

# Are select airlines getting better or worse?

*Mean annual delay by Year*



# Are select airlines getting better or worse?

*Mean annual delay by Year*

```
ontimeSubset <- subset(ONTIME_S, UNIQUECARRIER %in% c("AA", "AS", "CO", "DL","WN","NW"))

res22 <- with(ontimeSubset, tapply(ARRDELAY, list(UNIQUECARRIER, YEAR), mean, na.rm =
TRUE))

g_range <- range(0, res22, na.rm = TRUE)
rindex <- seq_len(nrow(res22))
cindex <- seq_len(ncol(res22))
par(mfrow = c(2,3))
for(i in rindex) {
  temp <- data.frame(index = cindex, avg_delay = res22[i,])
  plot(avg_delay ~ index, data = temp, col = "black",
       axes = FALSE, ylim = g_range, xlab = "", ylab = "",
       main = attr(res22, "dimnames")[[1]][i])
  axis(1, at = cindex, labels = attr(res22, "dimnames")[[2]])
  axis(2, at = 0:ceiling(g_range[2]))
  abline(lm(avg_delay ~ index, data = temp), col = "green")
  lines(lowess(temp$index, temp$avg_delay), col="red")
}
```

# R Object Persistence in Oracle Database

# R Object Persistence

*What does R provide?*

save()

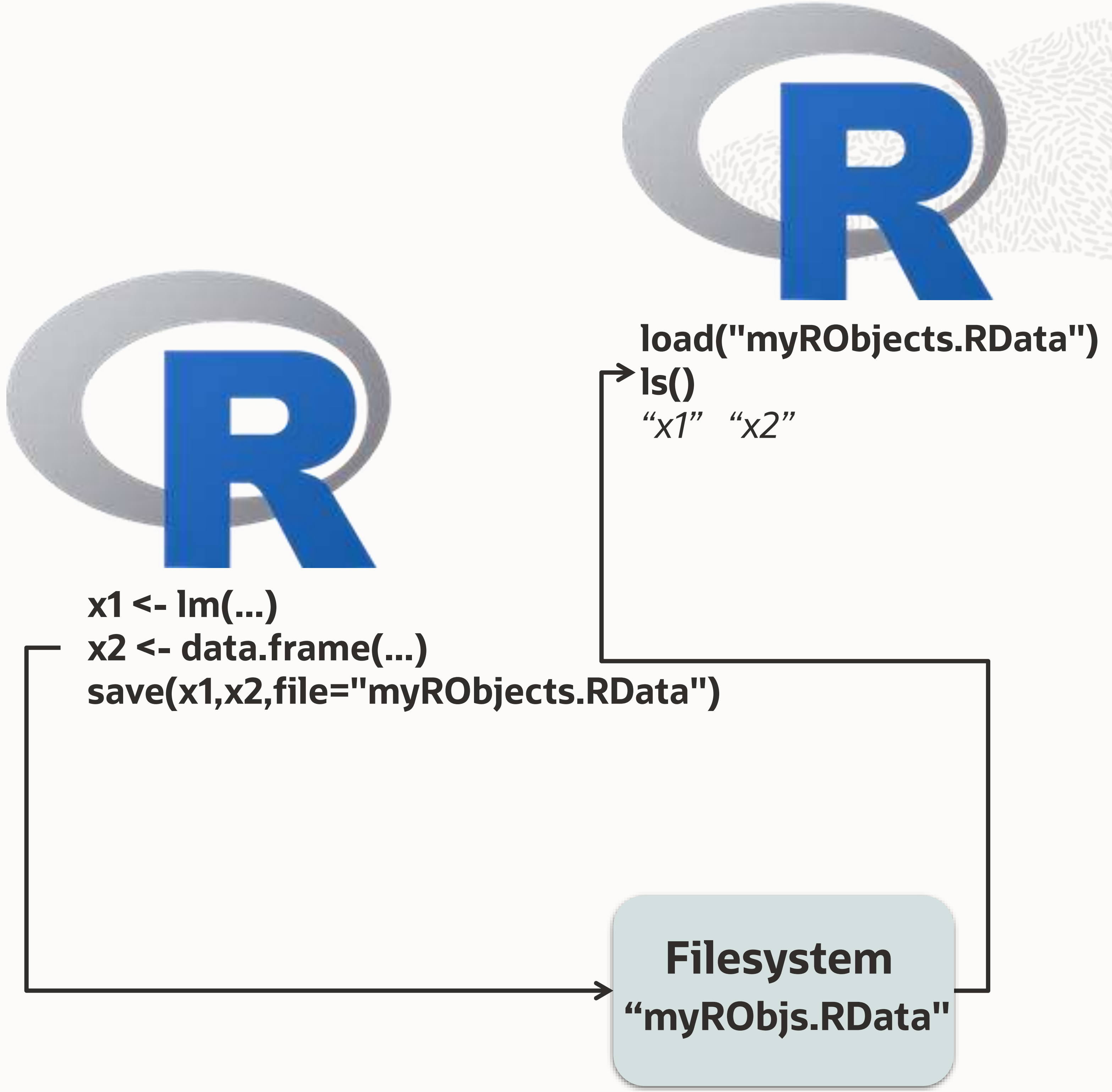
load()

Serialize and unserialize R objects to files

Standard R functions to persist R objects do not interoperate with Oracle Database

Use cases include

- Persist models for subsequent data scoring
- Save entire R state to reload next R session



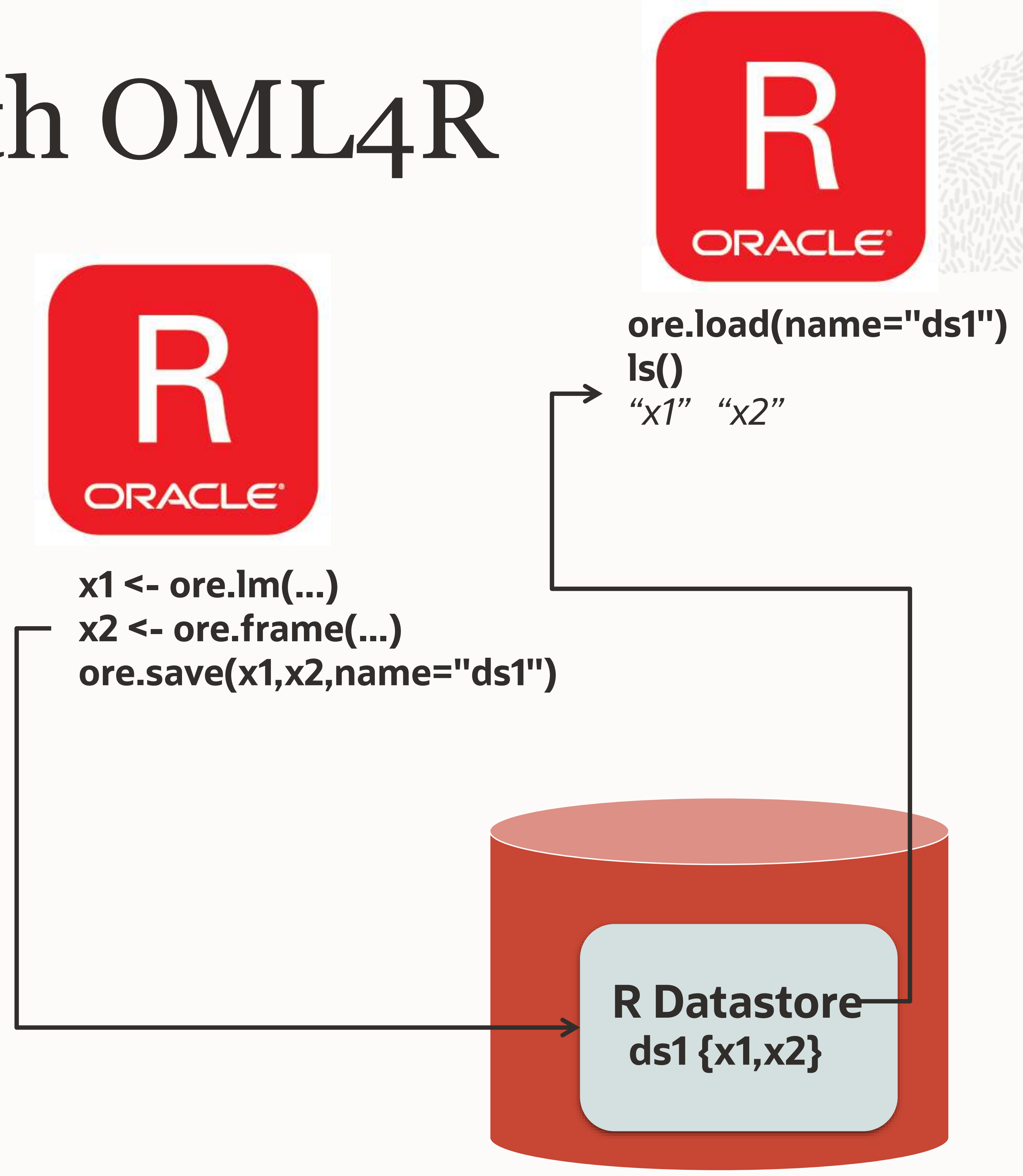
# R Object Persistence with OML4R

ore.save()
ore.load()

Provide database storage to save/restore R and OML4R objects across R sessions

Use cases include

- Enable passing of predictive model for embedded R execution, instead of recreating them inside the R functions
- Passing arguments to R functions with embedded R execution
- Preserve OML4R objects across R sessions



# Datastore Details

Each schema has its own datastore table where R objects are saved as named datastores

Maintain referential integrity of saved objects

- Account for objects auto-deleted at end of session
- Database objects, such as tables, ODM models, etc., not used by any saved R object is deleted when R session ends

Functions

- ore.save, ore.load
- ore.datastore, ore.datastoreSummary
- ore.delete
- ore.grant, ore.revoke

# ore.save

```
DAT1          <- ore.push(ONTIME_S[,c("ARRDELAY", "DEPDELAY", "DISTANCE")])
ore.lm.mod    <- ore.lm(ARRDELAY ~ DISTANCE + DEPDELAY, DAT1 )
lm.mod        <- lm(mpg ~ cyl + disp + hp + wt + gear, mtcars)
nb.mod        <- ore.odmNB(YEAR ~ ARRDELAY + DEPDELAY + log(DISTANCE), ONTIME_S)
ore.save(ore.lm.mod, lm.mod, nb.mod, name = "myModels")
```

R objects and their referenced data tables are saved into the datastore of the connected schema

Saved R objects are identified with datastore name *myModels*

ore.save arguments

- ... — the R variables of the objects to be saved
- list — a character vector containing the names of objects to be saved
- name — datastore name to identify the set of saved R objects in current user's schema
- grantable — a logical value, if TRUE, read access to datastore can be granted to others
- envir — environment to search for objects to be saved
- overwrite — boolean indicating whether to overwrite the existing named datastore
- append — boolean indicating whether to append to the named datastore
- description — comments about the datastore
- envAsEmptyenv — a logical value indicating whether referenced environments in R objects to be saved should be replaced with an empty environment during serialization

# ore.load

```
ore.load(name = "myModels")
```

Accesses the R objects stored in the connected schema with datastore name "*myModels*"

These are restored to the R .GlobalEnv environment

Objects ore.*lm.mod, lm.mod, nb.mod* can now be referenced and used

Arguments

- name — datastore name under current user schema in the connected schema
- list — a character vector containing the names of objects to be loaded from the datastore, default is all objects
- envir — the environment where R objects should be loaded in R

# ore.datastore

```
dsinfo <- ore.datastore(pattern = "my*")
```

List basic information about R datastore in connected schema

Result *dsinfo* is a data.frame

- Columns:
  datastore.name, object.count (# objects in datastore), size (in bytes), creation.date, description
- Rows: one per datastore object in schema

Arguments

- name — name of datastore under current user schema from which to return data
- pattern — optional regular expression. Only the datastores whose names match the pattern are returned. By default, all the R datastores under the schema are returned
- type – An optional scalar character string specifying the type of datastore to list: 'user' (default), 'private', 'all', 'grantable', 'grant', or 'granted'

# ore.datastore example

```
R> ore.datastore()
  datastore.name object.count     size       creation.date description
1    myDatastore            1 64461835 2012-11-14 17:12:36        <NA>
2     myIrisData            1     5789 2012-11-14 19:07:18        <NA>
3       myModels            3    45782 2012-11-14 18:56:32        <NA>
R>
R> ore.datastore(pattern="*Mod*")
  datastore.name object.count  size       creation.date description
1       myModels            3 45782 2012-11-14 18:56:32        <NA>
```

# ore.datastoreSummary

```
objinfo <- ore.datastoreSummary(name = "myModels")
```

List names of R objects that are saved within named datastore in connected schema

Result *objinfo* is a data.frame

- Columns:
  object.name, class, size (in bytes), length (if vector),
  row.count (if data,frame), col.count (if data.frame)
- Rows: one per datastore object in schema

Argument

- name — name of datastore under current user schema from which to list object contents
- owner –optional character string specifying the owner of datastore to summarize

# ore.datastoreSummary example

```
R> ore.datastoreSummary("myModels")
  object.name       class  size length row.count col.count
1      lm.mod          lm 10352     12        NA        NA
2      nb.mod ore.odmNB 27015      9        NA        NA
3  ore.lm.mod      ore.lm  8415     11        NA        NA
R>
R> ore.datastoreSummary("myIrisData")
  object.name      class size length row.count col.count
1        iris data.frame 5789      5       150         5
```

# ore.delete

```
ore.delete(name = "myModels", list = character(0))
```

Deletes named datastore in connected schema and its corresponding objects

If objects saved in other datastores referenced the same objects, referenced objects are only cleaned up when there are no more references

Argument

- name — name of datastore under current user schema from which to return data
- list – optional character vector containing names of objects to delete from datastore. If not specified, entire datastore is deleted

# ore.grant and ore.revoke

```
ore.save(iris, name="ds_1", grantable=TRUE)          # create grantable datastores
ore.save(mtcars, name="ds_2", grantable=TRUE)

ore.grant(name="ds_1", type="datastore", user=NULL) # grant read to all users

ore.datastore(type="all")[,-5]                 # show all datastores
ore.datastore(type="grantable")[, -4]          # show grantable datastores
ore.datastore(type="grant")                    # show datastores where read granted

ore.revoke(name="ds_1", type="datastore", user=NULL)  # revoke grant
ore.datastore(type="grant")

ore.delete(name="ds_1")  # clean up
ore.delete(name="ds_2")
```

# ore.grant and ore.revoke

Arguments

- name – string name of R datastore
- type – string “datastore” or “rqscript” namespace within which to grant/revoke the read privilege
- user – optional string indicating user being granted/revoked read privilege. Default of NULL grants to all users, i.e., PUBLIC

```
R> ore.save(iris, name="ds_1", grantable=TRUE)        # create grantable datastores
R> ore.save(mtcars, name="ds_2", grantable=TRUE)
R>
R> ore.grant(name="ds_1", type="datastore", user=NULL) # grant read to all users
R>
R> ore.datastore(type="all")[,-5L]              # show all datastores
   owner datastore.name object.count size description
1 RQUSER           ds_1            1 5789        <NA>
2 RQUSER           ds_2            1 3798        <NA>
3 RQUSER         rqds_1            5 5904        <NA>
4 RQUSER         rqds_2            2  312        <NA>
5 RQUSER         rqds_3            1  935        <NA>
R> ore.datastore(type="grantable")[, -4L]       # show grantable datstores
  datastore.name object.count size description
1           ds_1            1 5789        <NA>
2           ds_2            1 3798        <NA>
3         rqds_3            1  935        <NA>
R> ore.datastore(type="grant")                  # show datastores where read granted
  datastore.name grantee
1           ds_1  PUBLIC
R>
R> ore.revoke(name="ds_1", type="datastore", user=NULL)  # revoke grant
R> ore.datastore(type="grant")
[1] datastore.name grantee
<0 rows> (or 0-length row.names)
R>
R> ore.delete(name="ds_1")  # clean up
[1] "ds_1"
R> ore.delete(name="ds_2")
[1] "ds_2"
```

# Corresponding SQL API

List available datastores

```
select * from rquser_DataStoreList
```

View contents of a given datastore

```
select * from rquser_DataStoreContents
  where dsname = 'ds_name';
```

Delete a datastore

```
rqDropDataStore('<ds_name>')
```

# Using datastore objects in embedded R SQL API

```
begin
 -- sys.rqScriptDrop('buildmodel_1');
  sys.rqScriptCreate('buildmodel_1',
    'function(dat, out.dsname, out.objname) {
       assign(out.objname, lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat, model = FALSE))
       ore.save(list=out.objname, name = out.dsname, overwrite=TRUE)
       cbind(dsname=out.dsname, ore.datastoreSummary(name= out.dsname))
    }');
end;
/
```

| | DSNAME | OBJNAME | CLASS | OBJSIZE | LENGTH | NROW | NCOL |
|---|---|---|---|---|---|---|---|
| 1 | ontime_model | lm.mod | lm | 52244070 | 12 | (null) | (null) |

```
-- build model
select * from table(rqTableEval(
  cursor(select ARRDELAY, DISTANCE, DEPDELAY from ONTIME_S),
  cursor(select 'ontime_model' as "out.dsname",'lm.mod' as "out.objname",
                1 as "ore.connect" from dual),
  'select * from rquser_datastoreContents',
  'buildmodel_1'));
```

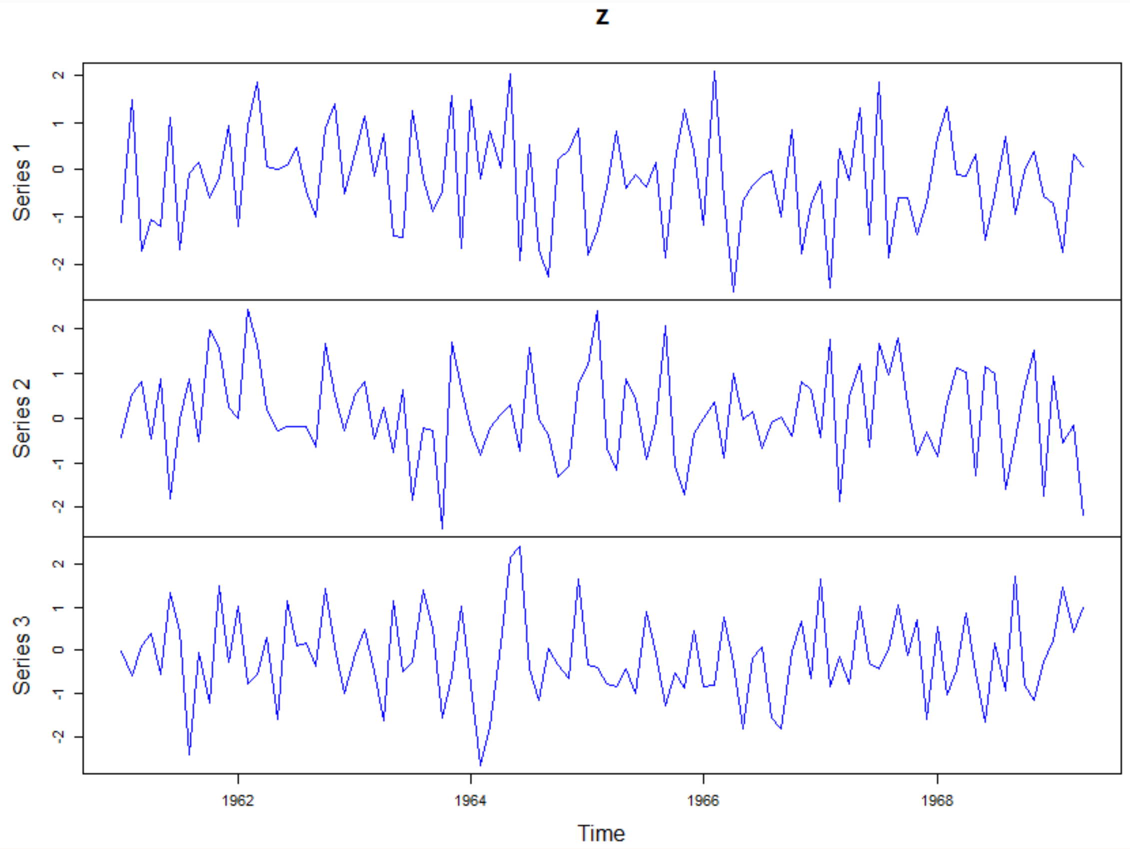
# Data Preparation support for Time Series Analytics

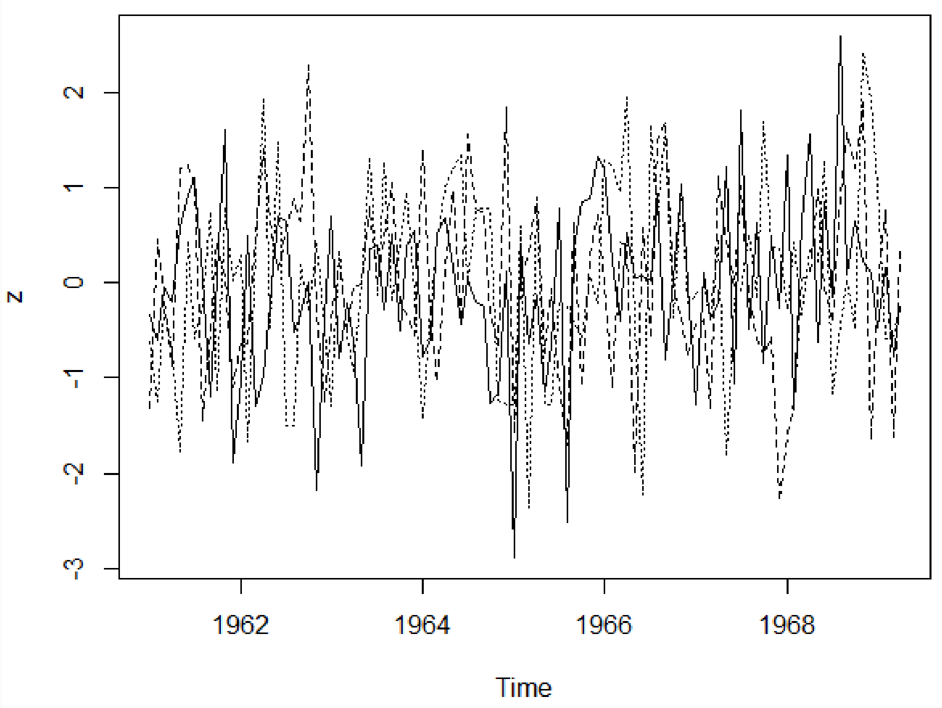
# Time Series Analysis
## *Motivation*

Time series data is widely prevalent

- Stock / trading data
- Sales data
- Employment data

Need to understand trends, seasonable effects, residuals

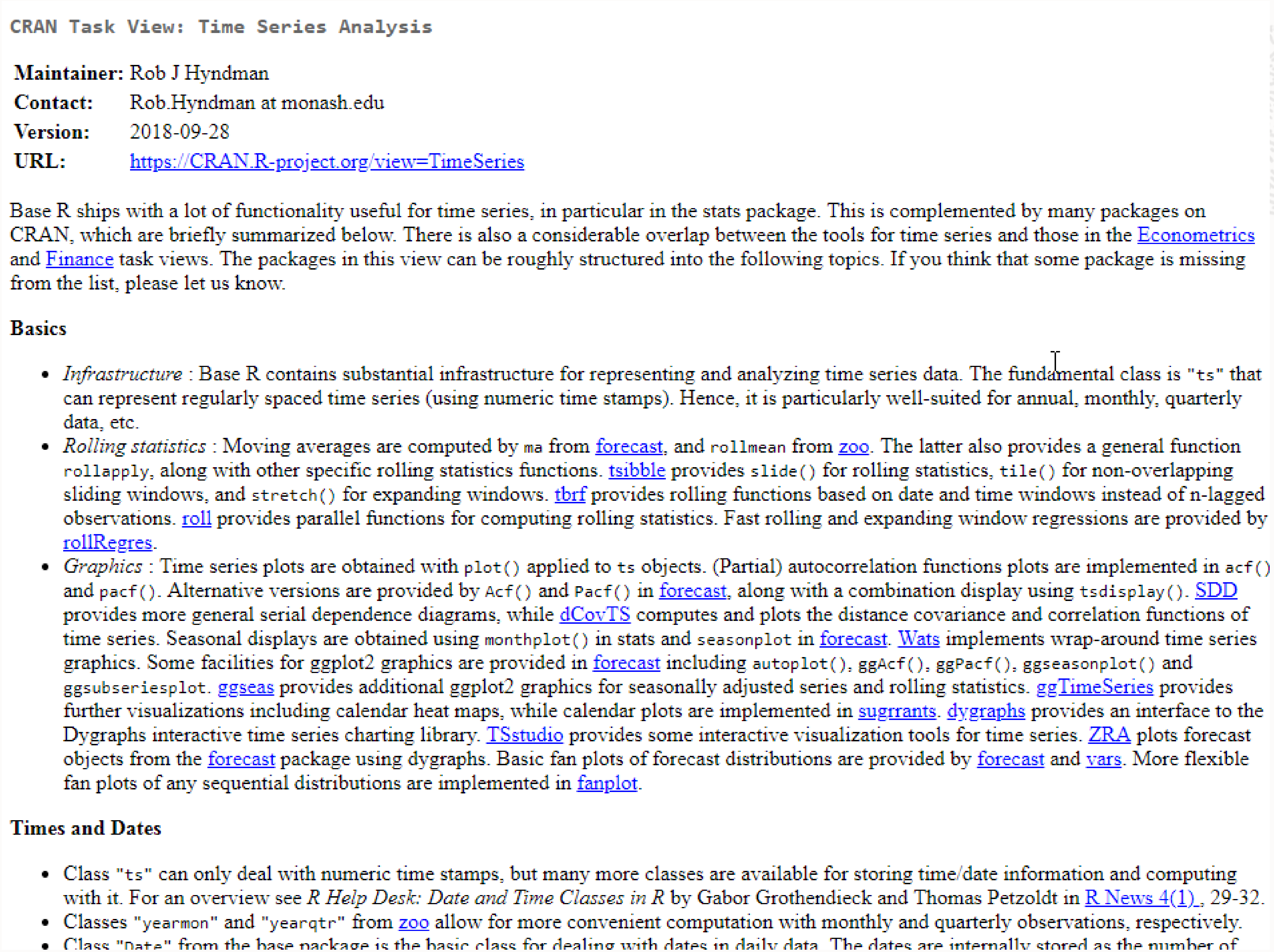


# Time Series Analysis

Aggregation and moving window analysis of large time series data

Equivalent functionality from popular R packages for data preparation available in-database


CRAN Task View: Time Series Analysis

**Maintainer:** Rob J Hyndman
**Contact:** Rob.Hyndman at monash.edu
**Version:** 2018-09-28
**URL:** https://CRAN.R-project.org/view=TimeSeries

Base R ships with a lot of functionality useful for time series, in particular in the stats package. This is complemented by many packages on CRAN, which are briefly summarized below. There is also a considerable overlap between the tools for time series and those in the Econometrics and Finance task views. The packages in this view can be roughly structured into the following topics. If you think that some package is missing from the list, please let us know.

**Basics**

- *Infrastructure* : Base R contains substantial infrastructure for representing and analyzing time series data. The fundamental class is `"ts"` that can represent regularly spaced time series (using numeric time stamps). Hence, it is particularly well-suited for annual, monthly, quarterly data, etc.
- *Rolling statistics* : Moving averages are computed by `ma` from forecast, and `rollmean` from zoo. The latter also provides a general function `rollapply`, along with other specific rolling statistics functions. tsibble provides `slide()` for rolling statistics, `tile()` for non-overlapping sliding windows, and `stretch()` for expanding windows. tbrf provides rolling functions based on date and time windows instead of n-lagged observations. roll provides parallel functions for computing rolling statistics. Fast rolling and expanding window regressions are provided by rollRegres.
- *Graphics* : Time series plots are obtained with `plot()` applied to `ts` objects. (Partial) autocorrelation functions plots are implemented in `acf()` and `pacf()`. Alternative versions are provided by `Acf()` and `Pacf()` in forecast, along with a combination display using `tsdisplay()`. SDD provides more general serial dependence diagrams, while dCovTS computes and plots the distance covariance and correlation functions of time series. Seasonal displays are obtained using `monthplot()` in stats and `seasonplot` in forecast. Wats implements wrap-around time series graphics. Some facilities for ggplot2 graphics are provided in forecast including `autoplot()`, `ggAcf()`, `ggPacf()`, `ggseasonplot()` and `ggsubseriesplot`. ggseas provides additional ggplot2 graphics for seasonally adjusted series and rolling statistics. ggTimeSeries provides further visualizations including calendar heat maps, while calendar plots are implemented in sugrrants. dygraphs provides an interface to the Dygraphs interactive time series charting library. TSstudio provides some interactive visualization tools for time series. ZRA plots forecast objects from the forecast package using dygraphs. Basic fan plots of forecast distributions are provided by forecast and vars. More flexible fan plots of any sequential distributions are implemented in fanplot.

**Times and Dates**

- Class `"ts"` can only deal with numeric time stamps, but many more classes are available for storing time/date information and computing with it. For an overview see *R Help Desk: Date and Time Classes in R* by Gabor Grothendieck and Thomas Petzoldt in R News 4(1) , 29-32.
- Classes `"yearmon"` and `"yearqtr"` from zoo allow for more convenient computation with monthly and quarterly observations, respectively.
- Class `"Date"` from the base package is the basic class for dealing with dates in daily data. The dates are internally stored as the number of

https://cran.r-project.org/web/views/TimeSeries.html

# Support for Time Series Data

Oracle data types

- DATE, TIMESTAMP
- TIMESTAMP WITH TIME ZONE
- TIMESTAMP WITH LOCAL TIME ZONE

Analytic capabilities

- Date arithmetic, Aggregations & Percentiles
- Moving window calculations:
  ore.rollmax ore.rollmean ore.rollmin ore.rollsd
  ore.rollsum ore.rollvar

# Date and Time

*Motivation*

Support for key data types in Oracle Database and R

Date and time handling essential for time series data

Date and time representation unified in Oracle Database, but R lacks a standard structure and functions

- E.g., Date, POSIXct, POSIXlt, difftime in R base package
- Mapping data types important for transparent database access

# Mapping Oracle Date and Time Data Types to R

| Oracle SQL Data Type | OML4R Data Type |
|---|---|
| DATE | ore.datetime |
| TIMESTAMP | ore.datetime |
| TIMESTAMP WITH TIME ZONE | ore.datetime |
| TIMESTAMP WITH LOCAL TIME ZONE | ore.datetime |
| INTERVAL YEAR TO MONTH | ore.character |
| INTERVAL DAY TO SECOND | ore.difftime |

# Date and Time Transparency Layer functions

Binary operations

- Arithmetic ( +, -, *, / )
- Comparison ( ==. <, >, !, <=, >= )

Row functions

- Component extraction (year, month, day, etc.)
- General operations (is.na, %in%, etc.)
- Number-like operations (round, trunc, etc.)

Vector operations

- Subsetting ( "[", head, tail )
- Distinct values (unique)

Aggregates

- Date-time quantiles (min, max, median, quantile)
- Tabulations (table)

Set operations

- Row filtering by date-time comparisons)
- Row splitting/grouping by date-time (split)
- Joining by date-time (merge)

Group by analysis

- Univariate fixed group aggregations by date-time characteristics (aggregate, tapply, by, etc.)

Moving window aggregation

- Univariate moving window aggregations of ordered data (ordering may or may not be date-time related)

# Date and Time aggregates

```
N <- 500
mydata <- data.frame(datetime =
             seq(as.POSIXct("2001/01/01"),
                 as.POSIXct("2001/12/31"),
                 length.out = N),
             difftime = as.difftime(runif(N),
                                    units = "mins"),
             x = rnorm(N))

MYDATA <- ore.push(mydata)
class(MYDATA)
class(MYDATA$datetime)
head(MYDATA,3)
```

```
R> class(MYDATA)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> class(MYDATA$datetime)
[1] "ore.datetime"
attr(,"package")
[1] "OREbase"
R> head(MYDATA,3)
             datetime        difftime          x
1 2001-01-01 00:00:00  8.862223 secs  0.1244691
2 2001-01-01 17:30:25 15.862898 secs -0.7189603
3 2001-01-02 11:00:50 51.942483 secs  0.1038590
```

# Date and Time aggregates

```
## statistic aggregates
min(MYDATA$datetime)
max(MYDATA$datetime)
range(MYDATA$datetime)
median(MYDATA$datetime)
quantile(MYDATA$datetime, probs = c(0, 0.05, 0.10))
```

```
R> ## Order statistic aggregates
R> min(MYDATA$datetime)
[1] "2001-01-01 EST"
R> max(MYDATA$datetime)
[1] "2001-12-31 EST"
R> range(MYDATA$datetime)
[1] "2001-01-01 EST" "2001-12-31 EST"
R> median(MYDATA$datetime)
[1] "2001-07-02 01:00:00 EDT"
R> quantile(MYDATA$datetime,
+           probs = c(0, 0.05, 0.10))
                      0%                        5%                       10%
"2001-01-01 00:00:00 EST" "2001-01-19 04:48:00 EST" "2001-02-06 09:36:00 EST"
```

# Date and Time arithmetic

```
## Arithmetic
day1Shift <- MYDATA$datetime +
             as.difftime(1, units = "days")
class(day1Shift)
head(MYDATA$datetime,3)
head(day1Shift,3)

lag1Diff <- diff(MYDATA$datetime)
class(lag1Diff)
head(lag1Diff,3)
```

```
R> ## Arithmetic
R> day1Shift <- MYDATA$datetime + as.difftime(1, units = "days")
R> class(day1Shift)
[1] "ore.datetime"
attr(,"package")
[1] "OREbase"
R> head(day1Shift,3)
[1] "2001-01-02 00:00:00 EST" "2001-01-02 17:30:25 EST"
[3] "2001-01-03 11:00:50 EST"
R>
R> lag1Diff <- diff(MYDATA$datetime)
R> class(lag1Diff)
[1] "ore.difftime"
attr(,"package")
[1] "OREbase"
R> head(lag1Diff,3)
Time differences in secs
[1] 63025.25 63025.25 63025.25
```

# Date and Time comparisons

```
isQ1 <- MYDATA$datetime < as.Date("2001/04/01")
class(isQ1)
head(isQ1,3)

isMarch <- isQ1 & MYDATA$datetime >
as.Date("2001/03/01")
class(isMarch)
head(isMarch,3)
sum(isMarch)

eoySubset <- MYDATA[MYDATA$datetime >
as.Date("2001/12/27"), ]
class(eoySubset)
head(eoySubset,3)
```

```
R> isQ1 <- MYDATA$datetime < as.Date("2001/04/01")
R> class(isQ1)
[1] "ore.logical"
attr(,"package")
[1] "OREbase"
R> head(isQ1,3)
[1] TRUE TRUE TRUE
R>
R> isMarch <- isQ1 & MYDATA$datetime > as.Date("2001/03/01")
R> class(isMarch)
[1] "ore.logical"
attr(,"package")
[1] "OREbase"
R> head(isMarch,3)
[1] FALSE FALSE FALSE
R> sum(isMarch)
[1] 43
R>
R> eoySubset <- MYDATA[MYDATA$datetime > as.Date("2001/12/27"), ]
R> class(eoySubset)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> head(eoySubset,3)
               datetime       difftime         x
495 2001-12-27 08:27:53  5.909428 secs  1.148956
496 2001-12-28 01:58:18 36.967094 secs -1.631579
497 2001-12-28 19:28:44 29.381100 secs  1.317894
```

# Date and Time accessors

```
## Date/time accessors
year <- ore.year(MYDATA$datetime)
unique(year)

month <- ore.month(MYDATA$datetime)
range(month)

dayOfMonth <- ore.mday(MYDATA$datetime)
range(dayOfMonth)

hour <- ore.hour(MYDATA$datetime)
range(hour)

minute <- ore.minute(MYDATA$datetime)
range(minute)

second <- ore.second(MYDATA$datetime)
range(second)
```

```
R> ## Date/time accessors
R> year <- ore.year(MYDATA$datetime)
R> unique(year)
[1] 2001
R>
R> month <- ore.month(MYDATA$datetime)
R> range(month)
[1]  1 12
R>
R> dayOfMonth <- ore.mday(MYDATA$datetime)
R> range(dayOfMonth)
[1]  1 31
R>
R> hour <- ore.hour(MYDATA$datetime)
R> range(hour)
[1]  0 23
R>
R> minute <- ore.minute(MYDATA$datetime)
R> range(minute)
[1]  0 59
R>
R> second <- ore.second(MYDATA$datetime)
R> range(second)
[1]  0.00000 59.87976
```

# Date and Time coercion

```
dateOnly <- as.ore.date(MYDATA$datetime)
class(dateOnly)
head(sort(unique(dateOnly)),3)

nameOfDay <- as.ore.character(MYDATA$datetime,
format = "DAY")
class(nameOfDay)
sort(unique(nameOfDay))

dayOfYear <-
as.integer(as.character(MYDATA$datetime,
format = "DDD"))
class(dayOfYear)
range(dayOfYear)

quarter <-
as.integer(as.character(MYDATA$datetime,
format = "Q"))
class(quarter)
sort(unique(quarter))
```

```
R> dateOnly <- as.ore.date(MYDATA$datetime)
R> class(dateOnly)
[1] "ore.date"
attr(,"package")
[1] "OREbase"
R> head(sort(unique(dateOnly)),3)
[1] "2001-01-01" "2001-01-02" "2001-01-03"
R>
R> nameOfDay <- as.ore.character(MYDATA$datetime, format = "DAY")
R> class(nameOfDay)
[1] "ore.character"
attr(,"package")
[1] "OREbase"
R> sort(unique(nameOfDay))
[1] "FRIDAY    " "MONDAY    " "SATURDAY " "SUNDAY    " "THURSDAY " "TUESDAY   "
[7] "WEDNESDAY"
R>
R> dayOfYear <- as.integer(as.character(MYDATA$datetime, format = "DDD"))
R> class(dayOfYear)
[1] "ore.integer"
attr(,"package")
[1] "OREbase"
R> range(dayOfYear)
[1]   1 365
R>
R> quarter <- as.integer(as.character(MYDATA$datetime, format = "Q"))
R> class(quarter)
[1] "ore.integer"
attr(,"package")
[1] "OREbase"
R> sort(unique(quarter))
[1] 1 2 3 4
```

# Arima example with rolling mean window function

```
row.names(MYDATA) <- MYDATA$datetime
MYDATA$rollmean5 <- ore.rollmean(MYDATA$x,
                                  k = 5)
MYDATA$rollsd5   <- ore.rollsd  (MYDATA$x,
                                  k = 5)
head(MYDATA)

marchData <- ore.pull(MYDATA[isMarch,])
tseries.x <- ts(marchData$x)
arima110.x <- arima(tseries.x, c(1,1,0))
predict(arima110.x, 3)

tseries.rm5 <- ts(marchData$rollmean5)
arima110.rm5 <- arima(tseries.rm5, c(1,1,0))
predict(arima110.rm5, 3)
```

```
R> row.names(MYDATA) <- MYDATA$datetime
R> MYDATA$rollmean5  <- ore.rollmean(MYDATA$x, k = 5)
R> MYDATA$rollsd5    <- ore.rollsd  (MYDATA$x, k = 5)
R> head(MYDATA, 3)
                               datetime      difftime          x  rollmean5   rollsd5
2001-01-01 00:00:00 2001-01-01 00:00:00 18.10307 secs -0.7592010  0.1176402 0.8656136
2001-01-01 17:30:25 2001-01-01 17:30:25 16.68061 secs  0.9715714  0.1310861 0.7072820
2001-01-02 11:00:50 2001-01-02 11:00:50 37.77584 secs  0.1405502 -0.1508768 0.8790343
R>
R> marchData <- ore.pull(MYDATA[isMarch,])
R> tseries.x <- ts(marchData$x)
R> arima110.x <- arima(tseries.x, c(1,1,0))
R> predict(arima110.x, 3)
$pred
Time Series:
Start = 44
End = 46
Frequency = 1
[1] -0.7801517 -0.8719835 -0.83

$se
Time Series:
Start = 44
End = 46
Frequency = 1
[1] 1.223900 1.458974 1.738310
```

```
R> tseries.rm5 <- ts(marchData$rollmean5)
R> arima110.rm5 <- arima(tseries.rm5, c(1,1,0))
R> predict(arima110.rm5, 3)
$pred
Time Series:
Start = 44
End = 46
Frequency = 1
[1] 0.4567869 0.4557631 0.4554896

$se
Time Series:
Start = 44
End = 46
Frequency = 1
[1] 0.2923064 0.4718523 0.6129770
```

# Ordering Framework

# Data Ordering

*Contrasting R and Database behavior*

**R**

- R's in-memory nature has a well-defined, implicit ordering of elements in vectors or objects based on vectors, e.g., data frames
- R supports integer indexing by default, e.g., df[1:4,]
- Notion of "unordered" data doesn't really exist in R

**DB**

- RDBMS data, e.g., tables and views, do not define an implicit ordering
- Enabling ordering involves having a primary key for tables and views
- Explicit ordering of data possible via ORDER BY clause, provided a unique ordering is possible, e.g., via single or multi-column key, but can impose a performance penalty

# Features of Ordering Framework

Ordering enables integer and character indexing on ore.frames

Distinguish between functions that require ordering and those that do not

- Throw error if unordered data types provided to functions requiring ordering
- Provide alternative semantics where possible if functions would normally require ordering and generate a warning only
  - e.g., head() and tail() can return sample of n rows instead of the top or bottom rows
- Ability to turn off ordering warnings

Use **row.names** and **row.names<-** functions for ordered frames

- Enables specifying unique identifier on an unordered ore.frame to make it ordered
- Convert between ordered and unordered types by setting/clearing row.names
- Can be comprised of multiple values, supporting multi-column keys

For tables with unique constraints, option to create ordered frames during ore.sync()

# Ordered and unordered ore.frame objects

An ore.frame is *ordered* if…

- A primary key is defined on the underlying table
- It is produced by certain functions, e.g., "aggregate" and "cbind"
- The row names of the ore.frame are set to unique values
- All input ore.frames to relevant OML4R functions are ordered

An ore.frame is *unordered* if…

- No primary key is defined on the underlying table
- Even with a primary key is specified, ore.sync parameter use.keys is set to FALSE
- No row names are specified for the ore.frame
- Row names have been set to NULL
- One or more input ore.frames to relevant OML4R functions are unordered

# Ordering Framework: Prepare and view the data

```
# R
library(kernlab)
data(spam)
s <- spam
s$TS <-as.integer(1:nrow(s)+1000)
s$USERID <- rep(1:50+350, each=2, len=nrow(s))
ore.drop(table='SPAM_PK')
ore.drop(table='SPAM_NOPK')
ore.create(s[,c(59:60,1:28)], table='SPAM_PK')
ore.create(s[,c(59:60,1:28)], table='SPAM_NOPK')

ore.exec('alter table SPAM_PK
add constraint SPAM_PK primary key ("USERID","TS")')

# R
head(SPAM_PK[,1:8])
head(SPAM_NOPK[,1:8])
```

```
R> head(SPAM_PK[,1:8])
              TS USERID make address  all num3d  our over
1001|351 1001    351 0.00    0.64 0.64     0 0.32 0.00
1002|351 1002    351 0.21    0.28 0.50     0 0.14 0.28
1003|352 1003    352 0.06    0.00 0.71     0 1.23 0.19
1004|352 1004    352 0.00    0.00 0.00     0 0.63 0.00
1005|353 1005    353 0.00    0.00 0.00     0 0.63 0.00
1006|353 1006    353 0.00    0.00 0.00     0 1.85 0.00
R>
R> head(SPAM_NOPK[,1:8])
    TS USERID make address  all num3d  our over
1 1001    351 0.00    0.64 0.64     0 0.32 0.00
2 1002    351 0.21    0.28 0.50     0 0.14 0.28
3 1003    352 0.06    0.00 0.71     0 1.23 0.19
4 1004    352 0.00    0.00 0.00     0 0.63 0.00
5 1005    353 0.00    0.00 0.00     0 0.63 0.00
6 1006    353 0.00    0.00 0.00     0 1.85 0.00
Warning messages:
1: ORE object has no unique key - using random order
2: ORE object has no unique key - using random order
```

# Using Keys

```
ore.sync(use.keys = FALSE)

head(  SPAM_PK[,1:4],3)
head(SPAM_NOPK[,1:4],3)

ore.sync() # use.keys TRUE default

head(  SPAM_PK[,1:4],3)
head(SPAM_NOPK[,1:4],3)

is.null(row.names(SPAM_PK))
```

```
R> ore.sync(use.keys = FALSE)
R> ore.attach()
R>
R> head(  SPAM_PK[,1:4],3)
    TS USERID make address
1 1001    351 0.00    0.64
2 1002    351 0.21    0.28
3 1003    352 0.06    0.00
Warning messages:
1: ORE object has no unique key - using random order
2: ORE object has no unique key - using random order
R> head(SPAM_NOPK[,1:4],3)
    TS USERID make address
1 1001    351 0.00    0.64
2 1002    351 0.21    0.28
3 1003    352 0.06    0.00
Warning messages:
1: ORE object has no unique key - using random order
2: ORE object has no unique key - using random order
R>
R> ore.sync()
R> ore.attach()
R>
R> head(  SPAM_PK[,1:4],3)
              TS USERID make address
1001|351 1001    351 0.00    0.64
1002|351 1002    351 0.21    0.28
1003|352 1003    352 0.06    0.00
R> head(SPAM_NOPK[,1:4],3)
    TS USERID make address
1 1001    351 0.00    0.64
2 1002    351 0.21    0.28
3 1003    352 0.06    0.00
Warning messages:
1: ORE object has no unique key - using random order
2: ORE object has no unique key - using random order
```

**Load proxy objects as unordered ore.frames**

**Notice that row names are sequential numbers by default**

**Warning issued**

**Same for SPAM_NOPK table**

**Load proxy objects as ordered ore.frames if primary key specified for table**

**Notice that row names consist of TS and USERID values separated by '|' character forming the row name**

**Notice also that since SPAM_NOPK does not have a primary key specified, it is still an unordered frame**

# Using row.names

```
a <-
ore.push(data.frame(a=c(1:10,
10:1), b=letters[c(1:10,
10:1)]))

a$b

row.names(head(a))

row.names(head(SPAM_NOPK))

row.names(head(SPAM_PK))

row.names(SPAM_PK) <-
SPAM_PK$TS

row.names(head(SPAM_PK[,1:4]))

head(SPAM_PK[,1:4])
```

```
R> a <- ore.push(data.frame(a=c(1:10, 10:1), b=letters[c(1:10, 10:1)]))
R> a$b
 [1] a b c d e f g h i j j i h g f e d c b a
Levels: a b c d e f g h i j
R>
R> row.names(head(a))
[1] "1" "2" "3" "4" "5" "6"
R>
R> row.names(head(SPAM_NOPK))
Error: ORE object has no unique key
In addition: Warning message:
ORE object has no unique key - using random order
R>
R> row.names(head(SPAM_PK))
[1] "1001|3.51E+002" "1002|3.51E+002" "1003|3.52E+002" "1004|3.52E+002"
R>
R> row.names(SPAM_PK) <- SPAM_PK$TS
R>
R> row.names(head(SPAM_PK[,1:4]))
[1] "1001" "1002" "1003" "1004" "1005" "1006"
R>
R> head(SPAM_PK[,1:4])
       TS USERID make address
1001 1001    351 0.00    0.64
1002 1002    351 0.21    0.28
1003 1003    352 0.06    0.00
1004 1004    352 0.00    0.00
1005 1005    353 0.00    0.00
1006 1006    353 0.00    0.00
```

**ore.frame created as ordered by default**
***note*: no warnings**

**Default row names**

**SPAM_NOPK has no unique key, so row.names raises error**

**Row names consist of TS '|' USERID**

**Reassign row names with TS only**

**Row names now correspond to TS value only**

# Indexing ore.frames

```
SPAM_PK["2060", 1:4]
SPAM_PK[as.character(2060:2064), 1:4]

SPAM_PK[2060:2062, 1:4]
```

```
...
R> SPAM_PK["2060", 1:4]
       TS USERID make address
2060 2060    380    0       0
R> SPAM_PK[as.character(2060:2064), 1:4]
       TS USERID make address
2060 2060    380    0       0
2061 2061    381    0       0
2062 2062    381    0       0
2063 2063    382    0       0
2064 2064    382    0       0
R>
R> SPAM_PK[2060:2062, 1:4]
       TS USERID make address
3060 3060    380    0    0.00
3061 3061    381    0    1.32
3062 3062    381    0    2.07
```

Index to a specifically named row

Index to a range of rows by row names

Index to a range of rows by integer index

# Merge Example

```
x <- SPAM_NOPK[,1:4]
y <- SPAM_NOPK[,c(1,2,4,5)]

m1 <- merge(x, y, by="USERID")
head(m1,3)

x <- SPAM_PK[,1:4]
y <- SPAM_PK[,c(1,2,4,5)]

m1 <- merge(x, y, by="USERID")
head(m1,3)
```

```
R> x <- SPAM_NOPK[,1:4]
R> y <- SPAM_NOPK[,c(1,2,4,5)]
R>
R> m1 <- merge(x, y, by="USERID")
R> head(m1,3)
  USERID TS.x make address.x TS.y address.y  all
1    351 5601 0.00         0 1001      0.64 0.64
2    351 5502 0.00         0 1001      0.64 0.64
3    351 5501 0.78         0 1001      0.64 0.64
Warning messages:
1: ORE object has no unique key - using random order
2: ORE object has no unique key - using random order
R>
R> x <- SPAM_PK[,1:4]
R> y <- SPAM_PK[,c(1,2,4,5)]
R>
R> m1 <- merge(x, y, by="USERID")
R> head(m1,3)
          USERID TS.x make address.x TS.y address.y  all
1001|1001    351 1001    0      0.64 1001      0.64 0.64
1001|1002    351 1001    0      0.64 1002      0.28 0.50
1001|1101    351 1001    0      0.64 1101      0.00 0.00
```

Set up data for illustrating merge

Merged result completes with warning since not an ordered frame

Set up data for illustrating merge

Merged result with no warning since ordered frame

Notice that row names are concatenation of row names from x and y

# Ordering Framework Options

```
options("ore.warn.order")
options("ore.warn.order" = TRUE)
options("ore.warn.order" = FALSE)

options("ore.sep")
options("ore.sep" = "/")
options("ore.sep" = "|")

row.names(NARROW) <- NARROW[,c("ID", "AGE")]
ore.pull(head(NARROW), sep = '+')
```

```
R> row.names(NARROW) <- NARROW[,c("ID", "AGE")]
R> ore.pull(head(NARROW), sep = '+')
              ID GENDER AGE MARITAL_STATUS                  COUNTRY EDUCATION OCCUPATION YRS_RESIDENCE CLASS
101501+41 101501   <NA>  41         NeverM United States of America   Masters      Prof.             4     0
101502+27 101502   <NA>  27         NeverM United States of America     Bach.      Sales             3     0
101503+20 101503   <NA>  20         NeverM United States of America   HS-grad    Cleric.             2     0
101504+45 101504   <NA>  45        Married United States of America     Bach.      Exec.             5     1
101505+34 101505   <NA>  34         NeverM United States of America   Masters      Sales             5     1
101506+38 101506   <NA>  38        Married United States of America   HS-grad      Other             4     0
```

# Ordering Recommended Practice

Ordering is expensive in the database

Most operations in R do not need ordering

In ore.sync(), set **use.keys = FALSE** almost always UNLESS you know that you need more

If you are sampling data or you need integer indexing for any other purpose, then set **use.keys = TRUE** as you need ordered ore frames

# Global Options in OML4R

# Global Options in OML4R

## help(ore.options)

### Options for Reporting

- **ore.trace**: A logical value indicating whether iterative OML4R functions should print output at each iteration. Default: FALSE

### Options for Row Ordering

- **ore.sep**: A character string specifying the separator to use between multiple column row names of an 'ore.frame'.  Default: "|”
- **ore.warn.order**: A logical value indicating whether a warning should be issued when pulling an 'ore.frame' that lacks row names or an 'ore.vector' that lacks element names into memory.  Default: 'TRUE'

# Global Options in OML4R

## Options for Server Execution:

- **ore.parallel**: A preferred degree of parallelism to use in the embedded R job; either a positive integer greater than or equal to '2' for a specific degree of parallelism, a value of 'FALSE' or '1' for no parallelism, a value of 'TRUE' for the database's default for parallelism, or 'NULL' for the database default for the operation. OML4R will use the same DOP for all operations based on the ore.parallel setting. Default: NULL

## Options for Subsetting

- **ore.na.extract**: A logical value used during logical subscripting of an ore.frame or ore.vector object. When TRUE, rows or elements with an NA logical subscript produces rows or elements with NA values. When FALSE an NA logical subscript is interpreted as a FALSE value, resulting in the removal of the corresponding row or element. Default is FALSE, whereas TRUE would mimic how R treats missing value logical subscripting of data.frame and vector objects.

# In-database Sampling and Random Partitioning

# High performance in-database sampling techniques

Simple random sampling

Split data sampling

Systematic sampling

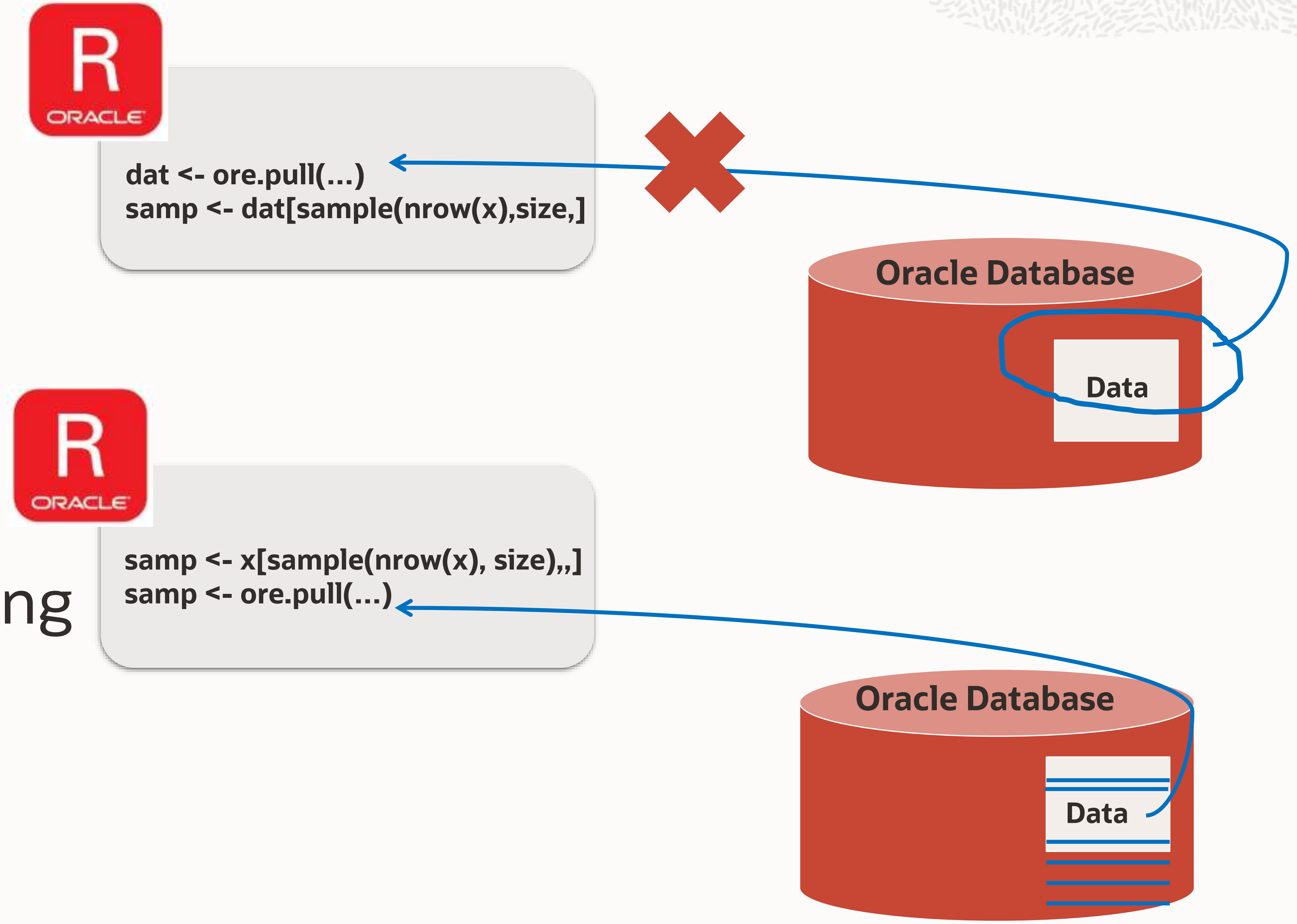
Stratified sampling

Cluster sampling

Quota sampling

Accidental / Convenience sampling

- via row order access
- via hashing



# In-database Sampling

## *Motivation*

R provides basic sampling capabilities, but requires data to be pre-loaded into memory

Catch 22

- Data too large to fit in memory, so need to sample
- Can’t sample because data won’t fit in memory

Minimize data movement by sampling in Oracle Database with OML4R ordering framework’s integer row indexing

# Simple random sampling

*Select rows at random*

```
set.seed(1)
N <- 20
myData <- data.frame(a=1:N,b=letters[1:N])
MYDATA <- ore.push(myData)
head(MYDATA)
sampleSize <- 5
simpleRandomSample <- MYDATA[sample(nrow(MYDATA),
                            sampleSize), ,
                            drop=FALSE]
class(simpleRandomSample)
simpleRandomSample
```

```
R> set.seed(1)
R> N <- 20
R> myData <- data.frame(a=1:N,b=letters[1:N])
R> MYDATA <- ore.push(myData)
R> head(MYDATA)
  a b
1 1 a
2 2 b
3 3 c
4 4 d
5 5 e
6 6 f
R> sampleSize <- 5
R> simpleRandomSample <- MYDATA[sample(nrow(MYDATA),
+                               sampleSize), ,
+                               drop=FALSE]
R> class(simpleRandomSample)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> simpleRandomSample
    a b
4   4 d
6   6 f
8   8 h
11 11 k
16 16 p
```

# Split data sampling

*Randomly partition data in train and test sets*

```
set.seed(1)

sampleSize <- 5
ind <- sample(1:nrow(MYDATA),sampleSize)
group <- as.integer(1:nrow(MYDATA) %in% ind)

MYDATA.train <- MYDATA[group==FALSE,]
dim(MYDATA.train)

class(MYDATA.train)

MYDATA.test <- MYDATA[group==TRUE,]
dim(MYDATA.test)
```

```
R> set.seed(1)
R>
R> sampleSize <- 5
R> ind <- sample(1:nrow(MYDATA),sampleSize)
R> group <- as.integer(1:nrow(MYDATA) %in% ind)
R>
R> MYDATA.train <- MYDATA[group==FALSE,]
R> dim(MYDATA.train)
[1] 15  2
R>
R> class(MYDATA.train)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R>
R> MYDATA.test <- MYDATA[group==TRUE,]
R> dim(MYDATA.test)
[1] 5 2
```

# Systematic sampling

*Select rows at regular intervals*

```
set.seed(1)
N <- 20
myData <- data.frame(a=1:20,b=letters[1:N])
MYDATA <- ore.push(myData)
head(MYDATA)
start <- 2
by <- 3
systematicSample <- MYDATA[seq(start, nrow(MYDATA),
                              by = by),
                          , drop=FALSE]
class(systematicSample)
systematicSample
```

```
R> set.seed(1)
R> N <- 20
R> myData <- data.frame(a=1:20,b=letters[1:N])
R> MYDATA <- ore.push(myData)
R> head(MYDATA)
  a b
1 1 a
2 2 b
3 3 c
4 4 d
5 5 e
6 6 f
R> start <- 2
R> by <- 3
R> systematicSample <- MYDATA[seq(start, nrow(MYDATA), by = by),
+                              , drop=FALSE]
R> class(systematicSample)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> systematicSample
    a b
2   2 b
5   5 e
8   8 h
11 11 k
14 14 n
17 17 q
20 20 t
```

# Stratified sampling

*Select rows within each group*

```
set.seed(1)
N <- 200
myData <- data.frame(a=1:N,b=round(rnorm(N),2),
                     group=round(rnorm(N,4),0))
MYDATA <- ore.push(myData)
head(MYDATA)
sampleSize <- 10
stratifiedSample <-
 do.call(rbind,
         lapply(split(MYDATA, MYDATA$group),
           function(y) {
            ny <- nrow(y)
            y[sample(ny, sampleSize*ny/N),,
              drop = FALSE]
           }))
class(stratifiedSample)
stratifiedSample
```

```
R> set.seed(1)
R> N <- 200
R> myData <- data.frame(a=1:N,b=round(rnorm(N),2),
+                       group=round(rnorm(N,4),0))
R> MYDATA <- ore.push(myData)
R> head(MYDATA)
  a     b group
1 1 -0.63     4
2 2  0.18     6
3 3 -0.84     6
4 4  1.60     4
5 5  0.33     2
6 6 -0.82     6
R> sampleSize <- 10
R> stratifiedSample <-
+     do.call(rbind,
+             lapply(split(MYDATA, MYDATA$group),
+                function(y) {
+                   ny <- nrow(y)
+                   y[sample(ny, sampleSize*ny/N),, drop = FALSE]
+                 }))
R> class(stratifiedSample)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> stratifiedSample
              a     b group
173|173 173  0.46     3
9|9           9  0.58     4
53|53       53  0.34     4
139|139 139 -0.65     4
188|188 188 -0.77     4
78|78       78  0.00     5
137|137 137 -0.30     5
```

# Stratified sampling

*ore.stratified.sample*

```
ore.drop("NARROW_SAMPLE_G")
ss <- ore.stratified.sample(x=NARROW, by="GENDER",
                            pct=0.1,
                            res.nm="NARROW_SAMPLE_G")
dim(NARROW_SAMPLE_G)
summary(NARROW_SAMPLE_G$GENDER)

ore.drop("R1_SAMPLE_G_MS")
res <- ore.stratified.sample(x=NARROW,
                   by=c("GENDER","MARITAL_STATUS"),
                   pct=0.1,
                   res.nm="R1_SAMPLE_G_MS")
dim(R1_SAMPLE_G_MS)
summary(R1_SAMPLE_G_MS$GENDER)
summary(R1_SAMPLE_G_MS$MARITAL_STATUS)
with(R1_SAMPLE_G_MS, table(GENDER,MARITAL_STATUS))
```

```
R> ore.drop("NARROW_SAMPLE_G")
R> ss <- ore.stratified.sample(x=NARROW, by="GENDER",
+                              pct=0.1,
+                              res.nm="NARROW_SAMPLE_G")
[1] "# of stratums(groups) to sample = 3, approx. # of sample = 150"
R> dim(NARROW_SAMPLE_G)
[1] 108   9
R> summary(NARROW_SAMPLE_G$GENDER)
 M  F
77 31
R>
R> ore.drop("R1_SAMPLE_G_MS")
R> res <- ore.stratified.sample(x=NARROW,
+                by=c("GENDER","MARITAL_STATUS"),
+                pct=0.1,
+                res.nm="R1_SAMPLE_G_MS")
[1] "# of stratums(groups) to sample = 21, approx. # of sample = 150"
[1] "10% is done "
[1] "20% is done "
[1] "29% is done "
[1] "39% is done "
[1] "48% is done "
[1] "58% is done "
[1] "67% is done "
[1] "77% is done "
[1] "86% is done "
[1] "96% is done "
R> dim(R1_SAMPLE_G_MS)
[1] 127   9
R> summary(R1_SAMPLE_G_MS$GENDER)
 M  F
81 46
R> summary(R1_SAMPLE_G_MS$MARITAL_STATUS)
Married  NeverM Divorc.  Separ. Widowed Mabsent
     53      33      26       7       6       2
R> with(R1_SAMPLE_G_MS, table(GENDER,MARITAL_STATUS))
      MARITAL_STATUS
GENDER Divorc. Mabsent Married NeverM Separ. Widowed
     F      17       2       5     11      5       6
     M       9       0      48     22      2       0
```

# Cluster sampling

*Select whole groups at random*

```
set.seed(1)
N <- 200
myData <- data.frame(a=1:N,b=round(runif(N),2),
                     group=round(rnorm(N,4),0))
MYDATA <- ore.push(myData)
head(MYDATA)
sampleSize <- 5
clusterSample <- do.call(rbind,
                         sample(split(MYDATA,
                                      MYDATA$group),2))
class(clusterSample)
unique(clusterSample$group)
```

```
R> set.seed(1)
R> N <- 200
R> myData <- data.frame(a=1:N,b=round(runif(N),2),
+                      group=round(rnorm(N,4),0))
R> MYDATA <- ore.push(myData)
R> head(MYDATA)
  a    b group
1 1 0.27     3
2 2 0.37     4
3 3 0.57     3
4 4 0.91     4
5 5 0.20     3
6 6 0.90     6
R> sampleSize <- 5
R> clusterSample <- do.call(rbind,
+                     sample(split(MYDATA, MYDATA$group), 2))
R> class(clusterSample)
[1] "ore.frame"
attr(,"package")
[1] "OREbase"
R> unique(clusterSample$group)
[1] 6 7
```

# Quota sampling

*Select first N rows*

```
set.seed(1)
N <- 200
myData <- data.frame(a=1:N,b=round(runif(N),2))
MYDATA <- ore.push(myData)

sampleSize <- 10
quotaSample1 <- head(MYDATA, sampleSize)
quotaSample1
```

```
R> set.seed(1)
R> N <- 200
R> myData <- data.frame(a=1:N,b=round(runif(N),2))
R> MYDATA <- ore.push(myData)
R>
R> sampleSize <- 10
R> quotaSample1 <- head(MYDATA, sampleSize)
R> quotaSample1
    a    b
1   1 0.27
2   2 0.37
3   3 0.57
4   4 0.91
5   5 0.20
6   6 0.90
7   7 0.94
8   8 0.66
9   9 0.63
10 10 0.06
```

# Data Types

# Data Types

*Mapping between R and Oracle Database*

| SQL – ROracle Read | R | SQL – ROracle Write |
|---|---|---|
| varchar2, char, clob, rowid | character | varchar2(4000) |
| number, float, binary_float, binary_double | numeric | if(ora.number==T) number else binary_double |
| integer | integer | integer |
| | logical | integer |
| date, timestamp | POSIXct | timestamp |
| | Date | timestamp |
| interval day to second | difftime | interval day to second |
| raw, blob, bfile | 'list' of 'raw' vectors | raw(2000) |
| | factor (and other types) | character |

# Create a data.frame with various types, then ore.frame

```
df <- data.frame(a="abc",
                 b=1.456,
                 c=TRUE,
                 d=as.integer(1),
                 e=Sys.Date(),
                 f=as.difftime(c("0:3:20", "11:23:15")))

str(df)
DF <- ore.push(df)
str(DF)
DF@desc$Sclass

DF$a <- as.ore.character(DF$a)
```

```
R> df <- data.frame(a="abc",
+                   b=1.456,
+                   c=TRUE,
+                   d=as.integer(1),
+                   e=Sys.Date(),
+                   f=as.difftime(c("0:3:20", "11:23:15")))
R>
R> str(df)
'data.frame':   2 obs. of  6 variables:
 $ a: Factor w/ 1 level "abc": 1 1
 $ b: num  1.46 1.46
 $ c: logi  TRUE TRUE
 $ d: int  1 1
 $ e: Date, format: "2014-01-26" "2014-01-26"
 $ f:Class 'difftime'  atomic [1:2] 3.33 683.25
  .. ..- attr(*, "tzone")= chr "EST5EDT"
  .. ..- attr(*, "units")= chr "mins"
R> DF <- ore.push(df)
R> str(DF)
'data.frame':   2 obs. of  6 variables:
Formal class 'ore.frame' [package "OREbase"] with 12 slots
  ..@ .Data    : list()
  ..@ dataQry  : Named chr "( select VAL007 NAME001,VAL008 NAME002, VAL001 ,VAL002 ,VAL003 ,VAL004 ,VAL005 ,VAL006  from ORE$1_459  )"
  .. ..- attr(*, "names")= chr "1_460"
  ..@ dataObj  : chr "1_460"
  ..@ desc     :'data.frame':   6 obs. of  2 variables:
  .. ..$ name  : chr  "a" "b" "c" "d" ...
  .. ..$ Sclass: chr  "factor" "numeric" "logical" "integer" ...
  ..@ sqlName  : Named chr  "VAL007" "VAL008"
  .. ..- attr(*, "names")= chr  "asc" ""
  ..@ sqlValue : chr  "VAL001" "VAL002" "VAL003" "VAL004" ...
  ..@ sqlTable : chr "ORE$1_459"
  ..@ sqlPred  : chr ""
  ..@ extRef   :List of 1
  .. ..$ :<environment: 0x1fd59158>
  ..@ names    : chr
  ..@ row.names: int
  ..@ .S3Class : chr "data.frame"
R> DF@desc$Sclass
[1] "factor"    "numeric"   "logical"   "integer"   "Date"      "difftime"
R>
R> DF$a <- as.ore.character(DF$a)
R> DF@desc$Sclass
[1] "character" "numeric"   "logical"   "integer"   "Date"      "difftime"
```

# CLOB and BLOB support in ore.push and ore.pull

```
R>       vbraw <- raw(3000L)
R>       attr(vbraw, "ora.type") <- "blob"
R>       oreBRaw <- ore.push(vbraw)
R>       class(oreBRaw)
[1] "ore.raw"
attr(,"package")
[1] "OREbase"
R>       new.vbraw <- ore.pull(oreBRaw)
R>       class(new.vbraw)
[1] "raw"
R>       length(new.vbraw)
[1] 3000
R> oreBRaw@sqlTable
[1] "\"RQUSER\".\"ORE$3_18\""
```

```
SQL> desc ORE$3_18
 Name                Null?         Type
 ---------------- -------- -----------
 VAL001                        BLOB
 VAL002                        NUMBER(38)
 VAL003                        NUMBER(38)
```

# Summary

*The purpose of the Transparency Layer is to support in-database data exploration, data preparation, and data analysis en route to application of machine learning algorithms, where we have a mix of in-database and CRAN techniques.*

OML4R provides transparency for in-database execution from R

It's transparent…

- R users need use only R syntax
- No need to learn a different programming paradigm or environment
- Users see database objects as proxy R objects to simplify interaction and manipulation

# For more information…

*oracle.com/machine-learning*


Database / Technical Details /
Machine Learning

Oracle Machine Learning

The Oracle Machine Learning product family enables scalable data science projects. Data scientists, analysts, developers, and IT can achieve data science project goals faster while taking full advantage of the Oracle platform.

Oracle Machine Learning consists of complementary components supporting scalable machine learning algorithms for in-database and big data environments, notebook technology, SQL and R APIs, and Hadoop/Spark environments.

See also [AskTOM OML Office Hours]

# Thank You

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