Session 3: Oracle Machine Learning for R
Embedded R Execution – R API

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Topics

Introduction to Embedded R Execution: What and Why?
Embedded R Scripts – using the R interface
Select Features
  • Working with connections and auto-connect
  • Generating image streams
  • Overloaded graphics function examples
Example of workflow for model building and scoring
Summary
Embedded R Execution

- Execute R code on the database server machine
- Have Oracle Database control and manage spawning of R engines
- Eliminate loading data to user’s client R engine and result write-back to Oracle Database
- Execute user-defined R functions using data- and task-parallelism
- Invoke R from SQL and return results in Oracle tables
- Use open source CRAN packages at the database server
- Store and manage user-defined R functions in the database
- Schedule user-defined R functions for automatic execution
Motivation – why embedded R execution?

Facilitate application use of R script results
• Develop/test user-defined R functions interactively with R interface
• Invoke user-defined R functions directly from SQL for production applications
• User-defined R functions – *scripts* – stored in Oracle Database

Improved performance and throughput
• Oracle Database-enabled data- and task-parallelism
• Memory and compute resources of database server, e.g., Exadata
• More efficient read/write of data between Oracle Database and R Engine
• Parallel simulations

Image/plot generation at database server
Rich XML for structured and image (PNG) data
Embedded R Execution – R Interface
## Embedded Script Execution – R Interface

*Execute R scripts at the database server*

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<td>Invoke stand-alone R script</td>
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<tr>
<td>ore.tableApply()</td>
<td>Invoke R script with ore.frame as input</td>
</tr>
<tr>
<td>ore.rowApply()</td>
<td>Invoke R script on one row at a time, or multiple rows in chunks from ore.frame</td>
</tr>
<tr>
<td>ore.groupApply()</td>
<td>Invoke R script on data partitioned by grouping column of an ore.frame</td>
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<tr>
<td>ore.indexApply()</td>
<td>Invoke R script N times</td>
</tr>
<tr>
<td>ore.scriptCreate()</td>
<td>Create an R script in the database repository</td>
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<tr>
<td>ore.scriptList()</td>
<td>List the R scripts in the repository</td>
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<tr>
<td>ore.scriptLoad()</td>
<td>Load an R script by name from the repository</td>
</tr>
<tr>
<td>ore.scriptDrop()</td>
<td>Drop an R script in the database repository</td>
</tr>
<tr>
<td>ore.grant()</td>
<td>Grant access to an R script to a user</td>
</tr>
<tr>
<td>ore.revoke()</td>
<td>Revoke access to an R script to a user</td>
</tr>
</tbody>
</table>
## Embedded Script Execution – R Interface

<table>
<thead>
<tr>
<th>OML4R function</th>
<th>Signature</th>
</tr>
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<tbody>
<tr>
<td>ore.doEval</td>
<td>ore.doEval(FUN, ..., FUN.VALUE = NULL, FUN.NAME = NULL)</td>
</tr>
<tr>
<td>ore.tableApply</td>
<td>ore.tableApply(X, FUN, ..., FUN.VALUE = NULL, FUN.NAME = NULL)</td>
</tr>
<tr>
<td>ore.rowApply</td>
<td>ore.rowApply(X, FUN, ..., FUN.VALUE = NULL, FUN.NAME = NULL, rows = 1,</td>
</tr>
<tr>
<td></td>
<td>parallel = getOption(&quot;ore.parallel&quot;, NULL))</td>
</tr>
<tr>
<td>ore.groupApply</td>
<td>ore.groupApply(X, INDEX, FUN, ..., FUN.VALUE = NULL, FUN.NAME = NULL,</td>
</tr>
<tr>
<td></td>
<td>parallel = getOption(&quot;ore.parallel&quot;, NULL))</td>
</tr>
<tr>
<td>ore.indexApply</td>
<td>ore.indexApply(times, FUN, ..., FUN.VALUE = NULL, FUN.NAME = NULL,</td>
</tr>
<tr>
<td></td>
<td>parallel = getOption(&quot;ore.parallel&quot;, NULL))</td>
</tr>
<tr>
<td>ore.scriptCreate</td>
<td>ore.scriptCreate(name, FUN, overwrite=FALSE, type)</td>
</tr>
<tr>
<td>ore.scriptList</td>
<td>ore.scriptList(name, pattern, type)</td>
</tr>
<tr>
<td>ore.scriptLoad</td>
<td>ore.scriptLoad(name, owner = NULL, newname = NULL, envir = parent.frame())</td>
</tr>
<tr>
<td>ore.scriptDrop</td>
<td>ore.scriptDrop(name, type)</td>
</tr>
<tr>
<td>ore.grant</td>
<td>ore.grant(name, type='rqscript', user)</td>
</tr>
<tr>
<td>ore.revoke</td>
<td>ore.revoke(name, type='rqscript', user)</td>
</tr>
<tr>
<td>OML4R function</td>
<td>Input data</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ore.doEval()</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>• Generated within R function</td>
</tr>
<tr>
<td></td>
<td>• Load via ore.pull</td>
</tr>
<tr>
<td></td>
<td>• Transparency layer</td>
</tr>
<tr>
<td></td>
<td>• ROracle data load</td>
</tr>
<tr>
<td></td>
<td>• Flat file data load</td>
</tr>
<tr>
<td>ore.tableApply()</td>
<td>• None</td>
</tr>
<tr>
<td>ore.rowApply()</td>
<td>• rows &gt;= 1, the maximum number of rows in each chunk</td>
</tr>
<tr>
<td>ore.groupApply()</td>
<td>• INDEX = list or ore.frame object referencing ore.factor objects/columns with same length as X</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>ore.indexApply()</td>
<td>• None</td>
</tr>
<tr>
<td></td>
<td>• Generated within R function</td>
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<tr>
<td></td>
<td>• Load via ore.pull</td>
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<td></td>
<td>• Transparency layer</td>
</tr>
<tr>
<td></td>
<td>• ROracle data load</td>
</tr>
<tr>
<td></td>
<td>• Flat file data load</td>
</tr>
</tbody>
</table>

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Using the R Script Repository

```r
ore.scriptCreate("MyLM",
    function(data, formula, ...) lm(formula, data, ...))
ore.scriptList(pattern="My")
ore.scriptLoad(name="MyLM", newname="MyNewLM")
ore.scriptDrop("MyLM")
ore.scriptCreate("MyNewLM", MyNewLM)

ore.grant(name="MyNewLM", type="rqscript")
ore.scriptList(type="grant")
ore.revoke(name="MyNewLM", type="rqscript")
ore.scriptList(type="grant")
ore.scriptDrop("MyNewLM")
```
ore.doEval – invoking a simple R script

```r
myFun <- function (num = 10, scale = 100) {
  ID <- seq(num)
  data.frame(ID = ID, RES = ID / scale)
}
options(ore.warn.order=FALSE)
res <- ore.doEval(myFun)
class(res)
res

local_res <- ore.pull(res)
class(local_res)
local_res
```

Goal: scale the first n integers by value provided
Result: a serialized R data.frame as an ore.object, which remains at the database server until retrieved by the client
> myFun <- function (num = 10, scale = 100) {
>     ID <- seq(num)
>     data.frame(ID = ID, RES = ID / scale)
> }
>
> res <- ore.doEval(myFun)

> class(res)
[1] "ore.object"
attr(,"package")
[1] "OREembed"

> res
   ID  RES
 1  1 0.01
 2  2 0.02
 3  3 0.03
 4  4 0.04
 5  5 0.05
 6  6 0.06
 7  7 0.07
 8  8 0.08
 9  9 0.09
10 10 0.10

> local_res <- ore.pull(res)
> class(local_res)
[1] "data.frame"

> local_res
     ID  RES
1     1 0.01
2     2 0.02
3     3 0.03
4     4 0.04
5     5 0.05
6     6 0.06
7     7 0.07
8     8 0.08
9     9 0.09
10    10 0.10
ore.doEval – specifying return value as ore.frame

```r
define myFun2 <- function (num = 10, scale = 100) {
  ID <- seq(num)
  data.frame(ID = ID, RES = ID / scale)
}

res <- ore.doEval(myFun2, FUN.VALUE = data.frame(ID = 1, RES = 1))
class(res)
res
```

```r
debug myFun2 <- function (num = 10, scale = 100) {
  ID <- seq(num)
  data.frame(ID = ID, RES = ID / scale)
}

res <- ore.doEval(myFun2, FUN.VALUE = data.frame(ID = 1, RES = 1))
class(res)
[1] "ore.frame"
attr("package")
[1] "OREbase"
res
  ID  RES
 1  1 0.01
 2  2 0.02
 3  3 0.03
 4  4 0.04
 5  5 0.05
 6  6 0.06
 7  7 0.07
 8  8 0.08
 9  9 0.09
10 10 0.10
```
ore.doEval – specifying parameters

```r
res <- ore.doEval(function (num = 10, scale = 100) {
    ID <- seq(num)
    data.frame(ID = ID,
                RES = ID / scale)
},
    num = 20, scale = 1000)
class(res)
res
```

```
> res <- ore.doEval(function (num = 10, scale = 100) {
    ID <- seq(num)
    data.frame(ID = ID, RES = ID / scale)
},
    num = 20, scale = 1000)
> class(res)
[1] "ore.object"
attr(,"package")
[1] "OREembed"
> res
  ID  RES
1  1 0.001
2  2 0.002
3  3 0.003
4  4 0.004
5  5 0.005
6  6 0.006
7  7 0.007
8 # NA NOR
```
ore.doEval – using the R script repository

```r
ore.scriptDrop("SimpleScript1")

ore.scriptCreate("SimpleScript1",
    function (num = 10, scale = 100) {
      ID <- seq(num)
      data.frame(ID = ID, RES = ID / scale)
    })

res <- ore.doEval(FUN.NAME="SimpleScript1",
    num = 20, scale = 1000)
```

> ore.scriptDrop("SimpleScript1")
> ore.scriptCreate("SimpleScript1",
+    function (num = 10, scale = 100) {
+      ID <- seq(num)
+      data.frame(ID = ID, RES = ID / scale)
+    })
>
> res <- ore.doEval(FUN.NAME="SimpleScript1",
+    num = 20, scale = 1000)
>
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.001</td>
</tr>
<tr>
<td>2</td>
<td>2.002</td>
</tr>
<tr>
<td>3</td>
<td>3.003</td>
</tr>
<tr>
<td>4</td>
<td>4.004</td>
</tr>
<tr>
<td>5</td>
<td>5.005</td>
</tr>
<tr>
<td>6</td>
<td>6.006</td>
</tr>
<tr>
<td>7</td>
<td>7.007</td>
</tr>
<tr>
<td>8</td>
<td>8.008</td>
</tr>
</tbody>
</table>

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ore.doEval – with other data types

```r
res <- ore.doEval(function (num = 10, scale = 100) {
  ID <- seq(num)
  data.frame(ID = ID, RES = ID / scale, CHAR="x")
},
  FUN.VALUE = data.frame(ID = 1, RES = 1, CHAR="a"))
class(res)
res
```

```r
res <- ore.doEval(function (num = 10, scale = 100) {
  ID <- seq(num)
  d <- data.frame(ID = ID, RES = ID / scale, CHAR="x")
  d$BOOL <- d$RES < 0.04
  d
},
  FUN.VALUE = data.frame(ID = 1, RES = 1, CHAR="a", BOOL=TRUE))
class(res)
res
```
TIP: How to define a FUN.VALUE with many columns of the same type?

```r
FUN.VALUE =
  data.frame(setNames(replicate(10,numeric(0), simplify = F),
                      paste("dim",1:10,sep="")))
```

```r
> FUN.VALUE
[1] dim1  dim2  dim3  dim4  dim5  dim6  dim7  dim8  dim9  dim10
<0 rows> (or 0-length row.names)
```
Regression – e.g. using lm or ore.lm

Predict a continuous numerical value

For a simple dataset with two variables, a line can be used to approximate the values

\[ y = mx + b \]

Build a model, i.e., compute coefficients, that can be expressed in terms of values \((m, b)\)

Models aren’t perfect…when used for scoring, or making predictions, they may have an error component

Metrics like Root Mean Square Error (RMSE) are useful for assessing and comparing models

Scoring can be batch or real-time
ore.doEval – pulling data from Oracle Database

mod <- ore.doEval(
  function() {
    ore.sync(table="ONTIME_S")
    dat <- ore.pull(ore.get("ONTIME_S"))
    lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
  },
  ore.connect = TRUE)

class(mod)
mod_local <- ore.pull(mod)
class(mod_local)
summary(mod_local)

• Goal: Build a single regression model retrieving data using Transparency Layer
• Data explicitly loaded into R memory at DB R Engine using ore.pull()
• Result “mod” returned as an ore.object
```r
R> mod <- ore.doEval(
+   function()
+   ore.sync(table="ONTIME_S")
+   dat <- ore.pull(ore.get("ONTIME_S"))
+   lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
+ ),
+ ore.connect = TRUE);
R> class(mod)
[1] "ore.object"
attr(,"package")
[1] "OREembed"
R> mod_local <- ore.pull(mod)
R> class(mod_local)
[1] "lm"
R> summary(mod_local)

Call:
  lm(formula = ARRDELAY ~ DISTANCE + DEPDELAY, data = dat)

Residuals:
   Min     1Q   Median     3Q    Max
-1462.45 -6.97  -1.36   5.07  925.08

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 2.254e-01  5.197e-02  4.336    1.45e-05 ***
DISTANCE  -1.218e-03  5.803e-05 -20.979   <2e-16 ***
DEPDELAY  9.625e-01  1.151e-03  836.289   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.73 on 215144 degrees of freedom
(4755 observations deleted due to missingness)
Multiple R-squared:  0.7647,  Adjusted R-squared:  0.7647
F-statistic: 3.497e+05 on 2 and 215144 DF,  p-value: < 2.2e-16
```
modCoef <- ore.tableApply(
  ONTIME_S[,c("ARRDELAY","DISTANCE","DEPDELAY")],
  function(dat, family) {
    mod <- glm(ARRDELAY ~ DISTANCE + DEPDELAY, 
      data=dat, family=family)
    coef(mod) 
  }, family=gaussian()
);
modCoef

• Goal: Build model on data from input cursor with parameter family = gaussian()
• Data set loaded into R memory as data.frame at DB R Engine and passed to function as first argument, x
• Result coefficient(mod) returned as R object
Results

R> modCoef <- ore.tableApply(
+   ONTIME_S[,c("ARRDELAY","DISTANCE","DEPDELAY")],
+   function(dat, family) {
+     mod <- glm(ARRDELAY ~ DISTANCE + DEPDELAY,
+                  data=dat, family=family)
+     coef(mod)
+   }, family=gaussian());
R> modCoef
  (Intercept)  DISTANCE   DEPDELAY
  0.225378249 -0.001217511  0.962528054
library(e1071)
mod <- ore.tableApply(
  ore.push(iris),
  function(dat) {
    library(e1071)
    dat$Species <- as.factor(dat$Species)
    naiveBayes(Species ~ ., dat)
  })
)
class(mod)
mod

- Goal: Build model on data from input cursor
- Package e1071 loaded at DB R Engine
- Data set pushed to database and then loaded into R memory at DB R Engine and passed to function
- Result “mod” returned as serialized object
IRIS <- ore.push(iris)
IRIS_PRED <- IRIS
IRIS_PRED$PRED <- "A"
res <- ore.tableApply(
  IRIS,
  function(dat, mod) {
    library(e1071)
    dat$PRED <- predict(mod, newdata = dat)
    dat
  },
  mod = ore.pull(mod),
  FUN.VALUE = IRIS_PRED
)
class(res)
head(res)

• Goal: Score data using model with data from ore.frame
• Return value specified using IRIS_PRED as example representation
• Result returned as ore.frame
scoreNBmodel <- function(dat, mod) {
  library(e1071)
  dat$PRED <- predict(mod, newdata = dat)
  dat
}

IRIS <- ore.push(iris)
IRIS_PRED <- IRIS
IRIS_PRED$PRED <- "A"

res <- ore.rowApply(
  IRIS,
  scoreNBmodel,
  mod = ore.pull(mod),
  FUN.VALUE = IRIS_PRED,
  rows=10)

class(res)
table(res$Species, res$PRED)

• Goal: Score data in batch (rows=10) using data from input ore.frame
• Data loaded into R memory at DB R Engine and passed to function
• Return value specified using IRIS_PRED as example representation
• Result returned as ore.frame

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ore.groupApply – partitioned data flow

```r
modList <- ore.groupApply(
  X=ONTIME_S,
  INDEX=ONTIME_S$DEST,
  function(dat) {
    lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
  }
)
summary(modList$BOS) ## return model for BOS
```
ore.groupApply – returning a single data.frame

```r
scoreReturningDF <- function(dat) {
  species <- as.character(dat$Species)
  mod <- lm(Sepal.Length ~ Sepal.Width + Petal.Length + Petal.Width, dat)
  prd <- predict(mod, newdata=dat)
  prd[as.integer(rownames(prd))] <- prd
  data.frame(Species = species, Sepal.Length = dat$Sepal.Length,
             PRED= prd, stringsAsFactors = FALSE)
}

IRIS <- ore.push(iris)
test <- ore.groupApply(IRIS, IRIS$Species,
                       scoreReturningDF,
                       FUN.VALUE = data.frame(Species = character(), Sepal.Length = numeric(0),
                                              PRED = numeric(),
                                              stringsAsFactors = FALSE),
                       parallel = TRUE)
# save results in database table TEST
ore.drop("TEST")
ore.create(test, "TEST")
```

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‘parallel’ argument

Preferred degree of parallelism to use in an embedded R job

Supported by…
• ore.groupApply
• ore.rowApply
• ore.indexApply

Values
• positive integer \( \geq 2 \) for a specific degree of parallelism
• 'FALSE' or 1 for no parallelism
• 'TRUE' takes on the 'data' argument's default parallelism
• 'NULL' for the database default for the operation
modList <- ore.groupApply(
  X=ONTIME_S,
  INDEX=ONTIME_S[,c("DEST","UNIQUECARRIER")],
  function(dat) {
    mod <- NULL
    try(mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat))
    mod
  }, parallel=16)
summary(modList$BOSAA) ## return model for BOS & AA

- Goal: Compute a linear model for each destination and airline (unique carrier) combination in parallel with requested 16 R engines
- View the model for Boston and AA
- Note: Some combinations have no data, so the try() is used
When does processing actually occur?

Case 1: Using `data.frame` for FUN.VALUE parameter
- `ore.groupApply` returns `ore.frame` promptly, which contains the underlying `rqGroupEval` call query
- The query execution is deferred to the point when `ore.frame` is pulled and the return of the query is relational data
  (there is no serialization/deserialization process taking place on the query result)

Case 2: No FUN.VALUE parameter (default to NULL)
- `ore.groupApply` returns `ore.list`, which contains `rqGroupEval` query execution result serialized into a temp table
- Query execution at the time `ore.groupApply` is called
- `ore.list` will go through deserialization to the R object when `ore.pull` is called (showing the result at R client)

For `ore.groupApply`, adding a FUN.VALUE parameter does two things
- Format the result to be a single `ore.frame`
- Changes when the processing occurs from time of `ore.groupApply` invocation to time of result `ore.frame` read

When the result from `ore.groupApply` is large, Option 1 could be faster than Option 2
- Option 1 does not involve (de)serialize process on the output
ore.indexApply – task-parallel execution

```r
illustrateIndexApply <- function(index, a, b, c) {
  x <- "Hi"
  paste(x, index, a, b, c, sep=":")
}

ore.indexApply(2, illustrateIndexApply, a=42, b="xyz", c=TRUE, parallel=TRUE)
```

- Goal: illustrate using index as input to vary behavior of function
- Return `ore.list`, one element per index for 2 indexes
Viewing database server-generated graphics in client

```r
ore.doEval(function(){
  set.seed(71)
  library(randomForest)
  iris.rf <- randomForest(Species ~ ., data=iris, importance=TRUE, proximity=TRUE)
  imp <- round(importance(iris.rf), 2) # Look at variable importance
  iris.mds <- cmdscale(1 - iris.rf$proximity, eig=TRUE) # Do MDS on 1 - proximity
  op <- par(pty="s")
  pairs(cbind(iris[,1:4], iris.mds$points), cex=0.6, gap=0,
        col=c("red", "green", "blue")[as.numeric(iris$Species)],
        main="Iris Data: Predictors and MDS of Proximity Based on RandomForest")
  par(op)
  list(importance = imp, GOF = iris.mds$GOF)
})
```

- Goal: generate graph at database server, view on client and return importance from R randomForest model
Results

```r
ore.doEval(function (){
  set.seed(71)
  iris.rf <- randomForest(Species ~ ., data=iris, importance=TRUE,
                           proximity=TRUE)
  ## Look at variable importance;
  inp <- round(importance(iris.rf), 2)
  ## Do MDS on 1 - proximity;
  iris.mds <- cmdscale(1 - iris.rf$proximity, eig=TRUE)
  op <- parpty="s")
  pairs(cbind(iris[,1:4], iris.mds$points), cex=0.6, gap=0,
        col=c("red", "green", "blue")as.numeric(iris$Species),
        main="Iris Data: Predictors and MDS of Proximity Based on RandomForest")
  par(op)
  list(importance = inp, GOF = iris.mds$GOF)
})
```

<table>
<thead>
<tr>
<th></th>
<th>setosa</th>
<th>versicolor</th>
<th>virginica</th>
<th>MeanDecreaseAccuracy</th>
<th>MeanDecreaseGini</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepal.Length</td>
<td>1.40</td>
<td>1.76</td>
<td>1.77</td>
<td>1.38</td>
<td>8.77</td>
</tr>
<tr>
<td>Sepal.Width</td>
<td>0.99</td>
<td>0.25</td>
<td>1.25</td>
<td>0.71</td>
<td>2.19</td>
</tr>
<tr>
<td>Petal.Length</td>
<td>3.72</td>
<td>4.37</td>
<td>4.26</td>
<td>2.90</td>
<td>42.54</td>
</tr>
<tr>
<td>Petal.Width</td>
<td>3.86</td>
<td>4.42</td>
<td>4.35</td>
<td>2.35</td>
<td>45.77</td>
</tr>
</tbody>
</table>

$GOF$

[1] 0.7842637 0.8183542
Parameterizing server-generated graphics in client

```r
ore.doEval(function (rounding = 2, colorVec= c("red", "green", "blue")){
  set.seed(71)
  library(randomForest)
  iris.rf <- randomForest(Species ~ ., data=iris, importance=TRUE, proximity=TRUE)
  ## Look at variable importance:
  imp <- round(importance(iris.rf), rounding)
  ## Do MDS on 1 - proximity:
  iris.mds <- cmdscale(1 - iris.rf$proximity, eig=TRUE)
  op <- par(pty="s")
  pairs(cbind(iris[,1:4], iris.mds$points), cex=0.6, gap=0,
        col=colorVec[as.numeric(iris$Species)],
        main="Iris Data: Predictors and MDS of Proximity Based on RandomForest")
  par(op)
  list(importance = imp, GOF = iris.mds$GOF)
},
rounding = 3, colorVec = c("purple","black","pink"))
```
Control Arguments Summary

Arguments starting with 'ore.' are special control arguments
- Not passed to the function specified by 'FUN' or 'FUN.NAME' arguments
- Controls what happens before or after the execution of the function

Supported control arguments include:
- **ore.drop** - controls the input data. If TRUE, a one column input data.frame will be converted to a vector (default: TRUE)
- **ore.na.omit** – controls missing value handling. If TRUE, rows or vectors with no data will be removed from processing
- **ore.connect** - controls whether to automatically connect to OML4R inside the closure. This is equivalent to doing an ore.connect call with the same credentials as the client session. (default: FALSE)
- **ore.graphics** - controls whether to start a graphical driver and look for images (default: TRUE)
- **ore.envAsEmptyenv** - controls whether referenced environments in an object should be replaced with an empty environment during serialization
- **ore.png.*** - if ore.graphics=TRUE, provides additional parameters for png graphics device driver. Use "ore.png." prefix to arguments of png function. E.g., if ore.png.height is supplied, argument “height” will be passed to the png function. If not set, the standard default values for the png function are used. See ?png for details

```r
png(filename = "Rplot%03d.png", width = 480, height = 480, units = "px", pointsize = 12, bg = "white", res = NA, ..., type = c("cairo", "cairo-png", "Xlib", "quartz"), antialias)
```
Viewing R Script Repository Contents

```r
ore.scriptList(name="Example1")
ore.scriptList(pattern="Ex")
ore.scriptList(type="user")
```

**type:** A scalar character string specifying the type of R script to list. 
- 'user' (default) lists scripts created by current session user.
- 'grant' lists scripts with the read privilege granted to other users.
- 'granted' lists scripts the current session user is granted
- 'global' lists all global R scripts
- 'all' lists all scripts to which the current session user has read access to

```r
# Alternatively, access these views directly
ore.sync(query = c(USER_RQ_SCRIPTS="select * from USER_RQ_SCRIPTS"))
row.names(USER_RQ_SCRIPTS) <- USER_RQ_SCRIPTS$NAME
USER_RQ_SCRIPTS$NAME  # List all scripts in SYS schema

ore.sync(query = c(ALL_RQ_SCRIPTS="select * from ALL_RQ_SCRIPTS"))
row.names(ALL_RQ_SCRIPTS) <- ALL_RQ_SCRIPTS$NAME
ALL_RQ_SCRIPTS$NAME  # List all scripts in SYS schema
```
Working with Connections
Connecting to databases from an embedded R function

Enable embedded R function executing in database to access and manipulate database tables using SQL (CRUD operations) without requiring explicit login

Scenario 1: Connect to the same database in which embedded R execution originated

• Login credentials are already available from the current active database session
• Steps: Obtain ROracle connection object. Use connection to execute queries. Disconnect
• Example

```r
con = dbConnect(Extproc())
...
dbGetQuery(con, 'query')
dbDisconnect(con)
```

Scenario 2: Connect to other databases or more than 1 database

• Login credentials not available since desired connection is to a different schema or different database instance
• Steps: Obtain connection object via explicit login, Use connection to execute queries, Disconnect when done
• Example

```r
con = dbConnect(Oracle(), "login credentials/connect string")
# OR con = dbConnect(Oracle(), "WALLET")
dbGetQuery(con, 'query');
dbDisconnect(con)
```
A few examples...

```r
ore.doEval(function(){
    ore.is.connected()  # returns FALSE
})

ore.doEval(function(){
    ore.is.connected(),  # returns TRUE
    ore.connect = TRUE
})

ore.doEval(function(){
    library(ORE)
    ore.connect("rquser", password = "rquser", conn_string = "inst1")
    ore.is.connected()  # returns TRUE
})
```
More examples...

```r
ore.doEval(function() {
  ore.sync(table = "NARROW")
  NARROW <- ore.get("NARROW")
  head(ore.pull(NARROW))
},
  ore.connect = TRUE)
```

```r
ore.doEval(function() {
  ore.sync(table = "NARROW")
  ore.attach()
  head(ore.pull(NARROW))
},
  ore.connect = TRUE)
```
Another example...

```r
ff <- function () {
    con = dbConnect(Extproc())
    dbGetQuery(con, "select * from NARROW where rownum < 3")
}
ore.doEval(ff)
```

```
R> ff <- function () {
+     con = dbConnect(Extproc())
+     dbGetQuery(con, "select * from NARROW where rownum < 3")
+ }  
R> ore.doEval(ff)

    ID    GENDER AGE MARITAL_STATUS          COUNTRY       EDUCATION   OCCUPATION  YRS_RESIDENCE CLASS
   1 101501    <NA>  41 NeverM United States of America Masters  Prof.       4      0
   2 101502    <NA>  27 NeverM United States of America  Bach.   Sales       3      0
```
Enabling multiple Package Versions

Support different users needing different versions of an R library with embedded R execution

Example

- **user1** needs to use SLAM slam_0.1-30.tar.gz because a more recent version may break their code
- **user2** wants to use a more recent SLAM (say slam_0.1-32.tar.gz)
- Requires that both versions of SLAM work with the ORD version in use on the database server machine
- Requires the newer SLAM is the "default" for the installation.

Approach:

- Maintain two different library paths
- First install the packages to the desired paths

At the OS shell:

```
export R_LIBS="/your/path1"
R CMD INSTALL -l /your/path1 slam_0.1-30.tar.gz

export R_LIBS="/your/path2"
R CMD INSTALL -l /your/path2 slam_0.1-32.tar.gz
```

Then, in R:

```
library(slam, lib.loc="/your/path1")  # loads slam version 0.1-30
library(slam, lib.loc="/your/path2")  # loads slam version 0.1-32
```

Within R:

```
install.packages("slam", lib="/your/path",
repos="http://cran.r-project.org")
```

Note this will only install the latest version of the package slam
Summary – OML4R Embedded R Execution

Easily invoke user-defined R functions at the database server machine
Control and secure R code that runs in Oracle Database
Use data- and task-parallelism for user-defined R functions
  • Parallelism using multiple database managed and controlled R engines
  • Control degree of parallelism from R API `parallel` argument
  • Parallel simulations
Product graphs at database server and return to R client
For more information...

oracle.com/machine-learning

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See also AskTOM OML Office Hours
Thank You

Mark Hornick
Oracle Machine Learning Product Management