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Session 4: Oracle Machine Learning for R

Embedded R Execution – SQL API

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Topics

Introduction to Embedded R Execution: What and Why?

Embedded R Scripts

- Execution through the SQL interface

Graph function examples

Returning R statistical results as a database table

Summary

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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

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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

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Embedded R Scripts – SQL Interface

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Embedded Script Execution – SQL Interface

SQL Interface function	Purpose
rqEval()	Invoke stand-alone R script
rqTableEval()	Invoke R script with full table as input
rqRowEval()	Invoke R script on one row at a time, or multiple rows in chunks
“rqGroupEval()”	Invoke R script on data partitioned by grouping column
sys.rqScriptCreate	Create named R script
sys.rqScriptDrop	Drop named R script
rqGrant	Grant access to an R script
rqRevoke	Revoke access to an R script

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rq*Eval() Table Functions

rqEval, rqTableEval, “rqGroupEval”, rqRowEval

```
rq*Eval(
  cursor(select * from <table-1>),
  cursor(select * from <table-2>),
  'select <column list> from <table-3> t',
  <grouping col-name from table-1
 or num rows>,
  '<R-script-name>')
```

Input cursor – Depending on the function, input passed as a whole table, group, or one row at a time to the R closure (not for rqEval)

Parameters cursor – Parameters are specified through a select statement, scalars only – single row

Output table definition – a query specifying the format of the result
If NULL, output is a serialized BLOB
If ‘PNG’, images only as BLOB column
If ‘XML’, XML string of images and return values

Group name (optional) – Name of the grouping column

Number of rows (optional) – number of rows to provide to function at one time

Name of R function in repository to execute

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Embedded Script Execution – SQL Interface

ERE function	Input data	FUN.VALUE	Arguments	R Script	Special
rqEval	None Generated within R function Load via ore.pull Transparency layer ROracle data load Flat file data load	NULL (returns chunked blob) table signature (returns table) XML PNG	NULL or Cursor with single row select statement with scalar values	R script name	Not applicable
rqTableEval	table cursor				Not applicable
rqRowEval					Integer >= 1
“rqGroupEval”					Single column name
sys.rqScriptCreate	Not applicable	Not applicable	R script name	R function	Not applicable
sys.rqScriptDrop			Not applicable	R script name	Not applicable

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Passing parameters

Directly pass **scalar numeric and string** values as R parameters via parameter cursor

```
select count(*)
from table(rqTableEval(
  cursor ( select x as "x", y as "y", parameter_value as "z"
           from geological_model_grid),
  cursor( select 30 as "levels", '/oracle/image.png' as "filename",
          1 "ore.connect" from dual),
  NULL,
  'Example5'));
```

To pass non-scalar R parameter (e.g., a model or list)

- use a *datastore* object – *preferred*
- construct string that can be parsed inside user-defined function

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rqEval – invoking a simple R script

```
begin
  --sys.rqScriptDrop('Example1')
  sys.rqScriptCreate('Example1',
'function() {
   ID <- 1:10
   res <- data.frame(ID = ID, RES = ID / 100)
   res}');
end;
/

select *
  from table(rqEval(NULL,
       'select 1 id, 1 res from dual',
       'Example1'));
```

```
SQL> begin
  sys.rqScriptCreate('Example1',
'function() {
   ID <- 1:10
   res <- data.frame(ID = ID, RES = ID / 100)
   res}');
end;
/
select *
  from table(rqEval(NULL,
       'select 1 id, 1 res from dual',
       'Example1'));
  2    3    4    5    6    7    8
PL/SQL procedure successfully completed.

SQL>   2    3    4
        ID        RES
---------- ----------
         1        .01
         2        .02
         3        .03
         4        .04
         5        .05
         6        .06
         7        .07
         8        .08
         9        .09
        10         .1

10 rows selected.
```

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Embedded R Execution – SQL Interface

For model build and batch scoring

```
begin
  sys.rqScriptDrop('Example2');
  sys.rqScriptCreate('Example2',
 'function(dat,datastore_name) {
   mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
   ore.save(mod,name=datastore_name, overwrite=TRUE)
   TRUE
  }');
end;
/

select *
  from table(rqTableEval(
     cursor(select ARRDELAY,
                   DISTANCE,
                   DEPDELAY
            from   ontime_s),
     cursor(select 1 as "ore.connect",
                   'myDatastore' as "datastore_name"
            from dual),
     'XML',
     'Example2' ));
```

```
begin
 sys.rqScriptDrop('Example3');
 sys.rqScriptCreate('Example3',
 'function(dat, datastore_name) {
     ore.load(datastore_name)
     prd <- predict(mod, newdata=dat)
     prd[as.integer(rownames(prd))] <- prd
     res <- cbind(dat, PRED = prd)
     res}');
end;
/
select *
from table(rqTableEval(
    cursor(select ARRDELAY, DISTANCE, DEPDELAY
           from   ontime_s
           where  year = 2003
           and    month = 5
           and    dayofmonth = 2),
    cursor(select 1 as "ore.connect",
                  'myDatastore' as "datastore_name" from dual),
    'select ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from ontime_s',
    'Example3'))
order by 1, 2, 3;
```

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Results

```
SQL> begin
  sys.rqScriptDrop('Example2');
  sys.rqScriptCreate('Example2',
 'function(dat,datastore_name) {
   mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
   ore.save(mod,name=datastore_name, overwrite=TRUE)
  }');
end;
/

select *
  from table(rqTableEval(
     cursor(select ARRDELAY,
                   DISTANCE,
                   DEPDELAY
            from   ontime_s),
     cursor(select 1 "ore.connect",
                   'myDatastore' as "datastore_name"
            from dual),
     'XML',
     'Examp  2    3    4    5    6    7    8    9  le2' ));


PL/SQL procedure successfully completed.

SQL> SQL>   2    3    4    5    6    7    8    9   10   11

NAME
--------------------------------------------------------------------
VALUE
--------------------------------------------------------------------

<root></root>
```

```
select *
from table(rqTableEval(
    cursor(select ARRDELAY, DISTANCE, DEPDELAY
           from   ontime_s
           where  year = 2003
           and    month = 5
           and    dayofmonth = 2),
    cursor(select 1 "ore.connect",
       2    3    4    5    6    7    8    9   10   11             'myDatastore' as "data
store_name" from dual),
    'select ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from ontime_s',
    'Example3'))
order by 1, 2, 3;

PL/SQL procedure successfully completed.

SQL>   2    3    4    5    6    7    8    9   10   11   12

  ARRDELAY   DISTANCE   DEPDELAY       PRED
---------- ---------- ---------- ----------
       -24       1190         -2 -3.1485154
       -20        185         -9 -8.6626137
       -16        697         -9 -9.2859791
       -15        859         -8 -8.5206878
       -15       2300         -4 -6.4250082
       -10        358          0 -.21049053
       -10        719         -8 -8.3502363
        -8        307         -2 -2.0734536
        -4       1050         -5 -5.8656481
        -3        150          5 4.85539194
        -2        140         -5 -4.7577135

  ARRDELAY   DISTANCE   DEPDELAY       PRED
---------- ---------- ---------- ----------
        -2        543         -2 -2.3607861
        -2       1530         -5 -6.4500532
```

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rqTableEval – singleton / real-time scoring

Pass cursor argument with values "selected" from dual

```
select *
from   table(rqTableEval(
         cursor(select 23 ARRDELAY, 3210 DISTANCE, 45 DEPDELAY
                from   dual),
         cursor(select 'myDatastore' "datastore_name",
                       1 "ore.connect" from dual),
        'select ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from ontime_s',
         'Example3'));
```

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rq*Eval functions: XML and PNG Image generation

Motivation

XML Generation

R script output is often dynamic – not conforming to pre-defined structure

- XML is very flexible and expressive

R applications generate heterogeneous data

- Statistics, new data, graphics, complex objects
- Applications R results may often need these results

Web-based applications typically can consume XML output

Database-based applications need ready integration of R executed via SQL

PNG Image Generation

Database-based applications can consume images directly from tables

R scripts can generate multiple images

- Enable returning image stream from R script
- Images directly returned as a table consisting of identifier and BLOB columns

Such results can be directly integrated with OBIEE for direct image access in dashboards

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rqEval – “Hello World!” XML Example

```
set long 20000
set pages 1000
begin
  sys.rqScriptCreate('Example4',
 'function() {"Hello World!"}');
end;
/
select name, value
  from table(rqEval(
        NULL,
       'XML',
       'Example4'));
```

```
---
SQL> set long 20000
set pages 1000
begin
  sys.rqScriptCreate('Example4',
 'function() {"Hello World!"}');
end;
/
select name, value
  from table(rqEval(
        NULL,
       'XML',
       'Example4'));
SQL> SQL>   2    3    4    5
PL/SQL procedure successfully completed.

SQL>   2    3    4    5
NAME
--------------------------------------------------------------------------------
VALUE
--------------------------------------------------------------------------------

<root><vector_obj><ROW-vector_obj><value>Hello World!</value></ROW-vector_obj></
vector_obj></root>
```

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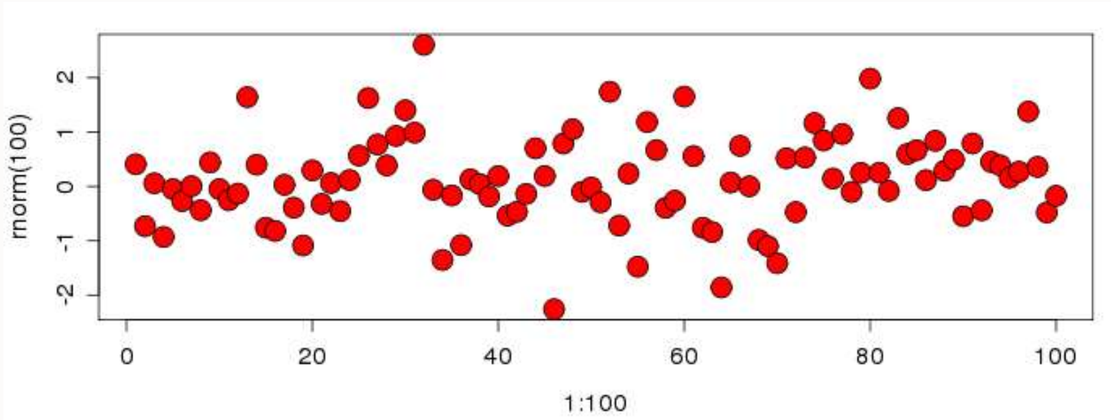
rqEval – generate XML string for image output

```
set long 20000
set pages 1000
begin
  sys.rqScriptDrop('Example5');
  sys.rqScriptCreate('Example5',
 'function(){
            res <- 1:10
            plot( 1:100, rnorm(100), pch = 21,
                  bg = "red", cex = 2 )
            res
            }');
end;
/
select    value
from      table(rqEval( NULL,'XML','Example5'));
```

- Executes function that plots 100 random numbers
- Returns a vector with values 1 to 10
- No parameters are specified
- Return the results as XML
- View the XML VALUE returned, which can be consumed by BI Publisher



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Results

```
SQL> begin
  sys.rqScriptDrop('Example5');
  sys.rqScriptCreate('Example5',
 'function(){
            res <- 1:10
            plot( 1:100, rnorm(100), pch = 21,
                  bg = "red", cex = 2 )
            res
            }');
end;
/
  2    3    4    5    6    7    8    9   10   11
PL/SQL procedure successfully completed.

SQL> select    value
from      table(rqEval( NULL,'XML','Example5'));
  2
VALUE
--------------------------------------------------------------------------------
```


```
<root><R-data><vector_obj><ROW-vector_obj><value>1</value></ROW-vector_obj><ROW-
vector_obj><value>2</value></ROW-vector_obj><ROW-vector_obj><value>3</value></RO
W-vector_obj><ROW-vector_obj><value>4</value></ROW-vector_obj><ROW-vector_obj><v
alue>5</value></ROW-vector_obj><ROW-vector_obj><value>6</value></ROW-vector_obj>
<ROW-vector_obj><value>7</value></ROW-vector_obj><ROW-vector_obj><value>8</value
></ROW-vector_obj><ROW-vector_obj><value>9</value></ROW-vector_obj><ROW-vector_o
bj><value>10</value></ROW-vector_obj></vector_obj></R-data><images><image><img s
rc="data:image/pngbase64"><![CDATA[iVBORw0KGgoAAAANSUhEUgAAAeAAAAHgCAYAAAB91L6VA
AAgAElEQVR4nOzdd3iT1fvH8XfSnaSDWSizgOwle8sGQZaiCA6UoSCCIDJEEGQvBdlD+DoQUYagIMgSE
BCRIUOmgCDKKkLbdI/790fRH2JH2iZN2t6uzudpk9x5xjnHICKCUkoppbKU0dkBlF0JKqdxICIC
```


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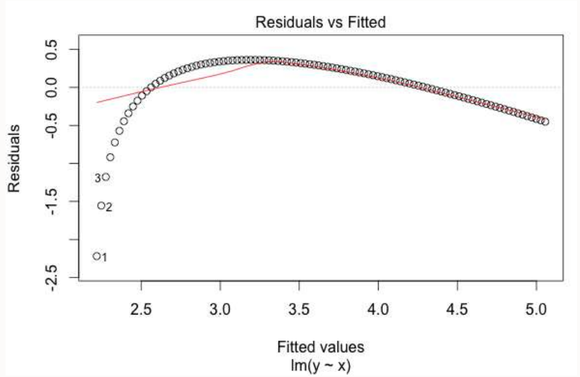
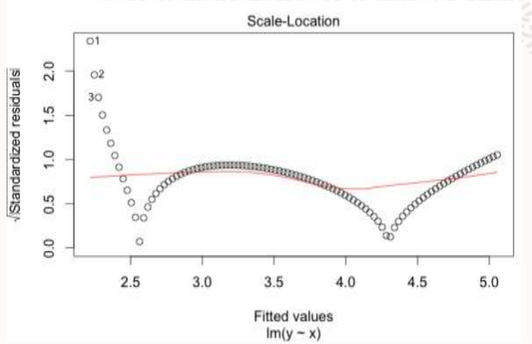
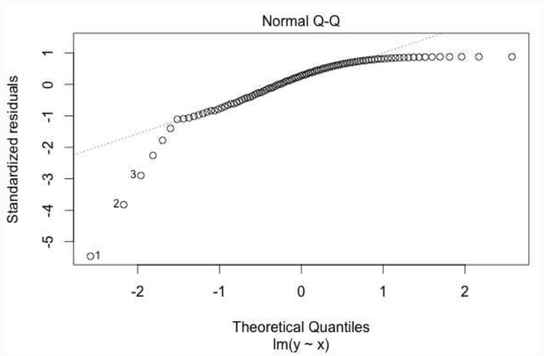
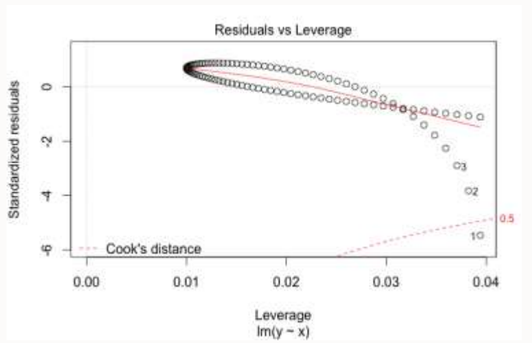
rqEval – generate PNG image stream

```
begin
  sys.rqScriptDrop('Example6');
  sys.rqScriptCreate('Example6',
 'function(){
            dat <- data.frame(y=log(1:100),
                              x = 1:100)
            plot(lm(y ~ x, dat))
            }');
end;
/
select    name, id, image
from      table(rqEval( NULL,'PNG','Example6'));
-- best viewed from SQL Developer
```









	NAME	ID	IMAGE
1	(null)	1	(BLOB)
2	(null)	2	(BLOB)
3	(null)	3	(BLOB)
4	(null)	4	(BLOB)

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Achieving “rqGroupEval” functionality

```
CREATE OR REPLACE PACKAGE ontimePkg AS
  TYPE cur IS REF CURSOR RETURN ontime_s%ROWTYPE;
END ontimePkg;
/
CREATE OR REPLACE FUNCTION ontimeGroupEval(
  inp_cur  ontimePkg.cur,
  par_cur  SYS_REFCURSOR,
  out_qry  VARCHAR2,
  grp_col  VARCHAR2,
  exp_txt  CLOB)
RETURN SYS.AnyDataSet
PIPELINED PARALLEL_ENABLE (PARTITION inp_cur BY HASH (month))
CLUSTER inp_cur BY (month)
USING rqGroupEvalImpl;
/
```

- Create SQL package for type of input cursor
- Create function with PIPELINED PARALLEL_ENABLE, partition by “group by” variable

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“rqGroupEval” build and rqRowEval score

```
begin
  --sys.rqScriptDrop('Example7');
  sys.rqScriptCreate('Example7',
 'function(dat) {
    mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
    name <- paste("mod",dat$MONTH[1],sep="")
    assign(name,mod)
    try(ore.save(list=name,
                 name="mydatastore",append=TRUE))
    TRUE}');
end;
/
select * from table(ontimeGroupEval(
    cursor(select /*+ parallel(t, 4) */ * from
   ontime_s t),
    cursor(select 1 as "ore.connect" from dual),
    'XML', 'MONTH', 'Example7'));
```

```
begin
  --sys.rqScriptDrop('Example8');
  sys.rqScriptCreate('Example8',
 'function(dat) {
      name <- paste("mod",dat$MONTH[1],sep="")
      ore.load("mydatastore",list=name)
      mod <- get(name)
      prd <- predict(mod, newdata=dat)
      prd[as.integer(rownames(prd))] <- prd
      cbind(dat, PRED = prd)}');
end;
/
select * from   table(rqRowEval(
  cursor(select /*+ parallel(t, 4) */ MONTH, ARRDELAY,
   DISTANCE, DEPDELAY
          from   ontime_s t
          where  year = 2003 and month in (5, 6)
          and    dayofmonth = 2),
  cursor(select 1 as "ore.connect" from dual),
  'select MONTH, ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from
   ontime_s',
     1, 'Example8'));
```

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“rqGroupEval” – multi-column

```
CREATE OR REPLACE PACKAGE ontimePkg AS
  TYPE cur IS REF CURSOR RETURN ontime_s%ROWTYPE;
END ontimePkg;
/
CREATE OR REPLACE FUNCTION ontimeGroupEval(
  inp_cur  ontimePkg.cur,
  par_cur  SYS_REFCURSOR,
  out_qry  VARCHAR2,
  grp_col  VARCHAR2,
  exp_txt  CLOB)
RETURN SYS.AnyDataSet
PIPELINED PARALLEL_ENABLE (PARTITION inp_cur BY HASH (year,
   month))
CLUSTER inp_cur BY (year, month)
USING rqGroupEvalImpl;
/
```

- Specify multiple column in HASH and BY

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“rqGroupEval” build and rqRowEval score – multi-column

```
begin
  --sys.rqScriptDrop('Example7a');
  sys.rqScriptCreate('Example7a',
 'function(dat) {
    mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
    name <- paste("mod", dat$YEAR[1],
                  dat$MONTH[1],sep="")
    assign(name,mod)
    try(ore.save(list=name,
                 name="mydatastore",append=TRUE))
    TRUE}');
end;
/
select * from table(ontimeGroupEval(
    cursor(select /*+ parallel(t, 4) */ * from
   ontime_s t),
    cursor(select 1 as "ore.connect" from dual),
    'XML', 'YEAR,MONTH', 'Example7a'));
```

```
begin
  --sys.rqScriptDrop('Example8a');
  sys.rqScriptCreate('Example8a',
 'function(dat) {
      name <- paste("mod", dat$YEAR[1],
                            dat$MONTH[1],sep="")
      ore.load("mydatastore",list=name)
      mod <- get(name)
      prd <- predict(mod, newdata=dat)
      prd[as.integer(rownames(prd))] <- prd
      cbind(dat, PRED = prd)}');
end;
/
select * from   table(rqRowEval(
  cursor(select /*+ parallel(t, 4) */ YEAR, MONTH,
   ARRDELAY, DISTANCE, DEPDELAY
          from   ontime_s t
          where  year > 2003 and month in (5, 6)
          and    dayofmonth = 2),
  cursor(select 1 as "ore.connect" from dual),
  'select YEAR, MONTH, ARRDELAY, DISTANCE, DEPDELAY, 1 PRED
   from ontime_s',
     1, 'Example8a'));
```

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“rqGroupEval” build – with minimal data

```
CREATE OR REPLACE PACKAGE ontimePkg AS
 TYPE rec IS RECORD (MONTH     NUMBER(38),
                     ARRDELAY  NUMBER(38),
                     DISTANCE    NUMBER(38),
                     DEPDELAY    NUMBER(38));
  TYPE cur IS REF CURSOR RETURN rec;
END ontimePkg;
/
CREATE OR REPLACE FUNCTION ontimeGroupEval(
  inp_cur  ontimePkg.cur,
  par_cur  SYS_REFCURSOR,
  out_qry  VARCHAR2,
  grp_col  VARCHAR2,
  exp_txt  CLOB)
RETURN SYS.AnyDataSet
PIPELINED PARALLEL_ENABLE (PARTITION inp_cur
   BY HASH (month))
CLUSTER inp_cur BY (month)
USING rqGroupEvalImpl;
/
```

```
begin
  --sys.rqScriptDrop('Example9');
  sys.rqScriptCreate('Example9',
 'function(dat) {
    mod <- lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
    name <- paste("mod",dat$MONTH[1],sep="")
    assign(name,mod)
    try(ore.save(list=name,name="mydatastore",append=TRUE))
    TRUE}');
end;
/

select *
  from table(ontimeGroupEval(
    cursor(select MONTH, ARRDELAY,
                  DISTANCE, DEPDELAY
           from ontime_s),
    cursor(select 1 as "ore.connect" from dual),
    'XML', 'MONTH', 'Example9'));
```

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rqRowEval – score

```
begin
  --sys.rqScriptDrop('Example10');
  sys.rqScriptCreate('Example10',
 'function(dat) {
      name <- paste("mod",dat$MONTH,sep="")
      ore.load("mydatastore",list=name)
      mod <- get(name)
      prd <- predict(mod, newdata=dat)
      prd[as.integer(rownames(prd))] <- prd
      cbind(dat, PRED = prd)}');
end;
/
select * from   table(rqRowEval(
  cursor(select /*+ parallel(t, 4) */ MONTH, ARRDELAY, DISTANCE, DEPDELAY
          from   ontime_s t
          where  year = 2003 and month in (5, 6)
          and    dayofmonth = 2),
  cursor(select 1 as "ore.connect" from dual),
  'select MONTH, ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from ontime_s', 1, 'Example10'));
```

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rqEval – with other data types

```
begin
  --sys.rqScriptDrop('Example11');
  sys.rqScriptCreate('Example11',
          'function (num = 10, scale = 100) {
              ID <- seq(num)
              data.frame(ID = ID, RES = ID / scale, CHAR="x")
              }');
end;
/
select * from table(rqEval(NULL,
                  'select 1 "ID", 1 "RES", ''a'' "CHAR" from dual',
                  'Example11'));
```

```
SQL> begin
  --sys.rqScriptDrop('Example11');
  sys.rqScriptCreate('Example11',
          'function (num = 10, scale = 100) {
              ID <- seq(num)
              data.frame(ID = ID, RES = ID / scale, CHAR="x")
              }');
end;
/
select * from table(rqEval(NULL,
                  'select 1 "ID", 1 "RES", ''a'' "CHAR" from dual',
                  'Example11'));
  2    3    4    5    6    7    8    9
PL/SQL procedure successfully completed.

SQL>   2    3
        ID        RES C
---------- ---------- -
         1        .01 x
         2        .02 x
         3        .03 x
         4        .04 x
         5        .05 x
         6        .06 x
         7        .07 x
         8        .08 x
         9        .09 x
        10         .1 x

10 rows selected.
```

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rqEval – with other data types

```
begin
  --sys.rqScriptDrop('Example12');
  sys.rqScriptCreate('Example12',
          '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
           }');
end;
/
select * from table(rqEval(NULL,
        'select 1 "ID", 1 "RES", ''a'' "CHAR1", 1 "BOOL" from dual',
        'Example12'));
```

```
SQL> begin
  --sys.rqScriptDrop('Example12');
  sys.rqScriptCreate('Example12',
          '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
           }');
end;
/
select * from table(rqEval(NULL,
        'select 1 "ID", 1 "RES", ''a'' "CHAR1", 1 "BOOL" from dual',
        'Example12'));
  2    3    4    5    6    7    8    9   10   11
PL/SQL procedure successfully completed.

SQL>   2    3
        ID        RES C       BOOL
---------- ---------- - ----------
         1        .01 x          1
         2        .02 x          1
         3        .03 x          1
         4        .04 x          0
         5        .05 x          0
         6        .06 x          0
         7        .07 x          0
         8        .08 x          0
         9        .09 x          0
        10         .1 x          0

10 rows selected.
```

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rq*Eval Output Specification Summary

Output Type Parameter Value	Data Returned
SQL table specification string e.g., “select 1 ID, ‘aaa’ VAL from dual”	Table – streamed structured data Image stream is discarded
‘XML’	XML string May contain both data and image data Images represented as base 64 encoding of PNG
‘PNG’	Structured output data ignored Table with 1 image per row NAME varchar2(4000) ID number IMAGE blob

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Embedded R Execution – Privileges

Database Roles	R Interface	SQL Interface
RQADMIN	Execute ore.doEval and ore.*Apply functions Use FUN argument to dynamically create R scripts Execute ore.scriptCreate and ore.scriptDrop functions Access USER_RQ_SCRIPTS or ALL_RQ_SCRIPTS views Execute ore.grant and ore.drop functions	Execute rq*Eval functions Execute sys.rqScriptCreate and sys.rqScriptDrop functions Access USER_RQ_SCRIPTS or ALL_RQ_SCRIPTS views Execute rqGrant and rqDrop functions Execute rqConfigSet function

```
grant RQADMIN to <USER>;
```

Note that any user can invoke embedded R scripts that are public in the R Script Repository

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Embedded Graphic Function Examples

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Why use embedded R graph functions?

Same reasons for embedded R in general

- More powerful database server
- More efficient transfer of data between database and R engine
- Execute scripts from SQL

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Graph function examples

OML4R-defined scripts with a reserved name prefix: ‘RQG$'

Prefix followed by a function name from 'graphics’ package that the script wraps

Depending on function, takes either the first, the first and second, or all columns of the input 'data.frame'

For use with

- ore.tableApply, rqTableEval
- ore.groupApply, “rqGroupEval”
- ore.rowApply, rqRowEval

Each function allows '...' parameters to enable passing graphics function parameters to the wrapped function

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OML4R-defined graphics function examples

Embedded R Function	Wraps R Function	Performs function on … of input ore.frame object
RQG$plot1d	plot	first column
RQG$plot2d	plot	first two columns
RQG$hist	hist	first column
RQG$boxplot	boxplot	first column
RQG$smoothScatter	smoothScatter	first two columns
RQG$cdplot	cdplot	first two columns
RQG$pairs	pairs	all columns
RQG$matplot	matplot	all columns

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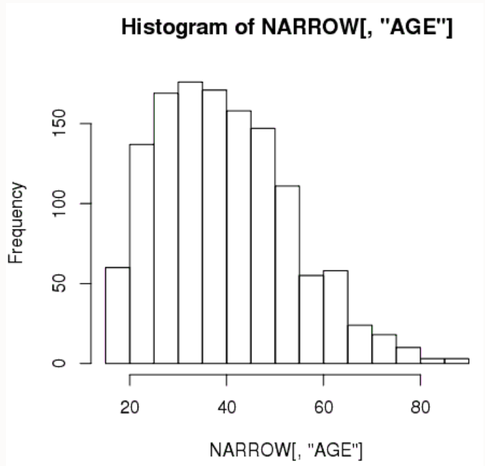
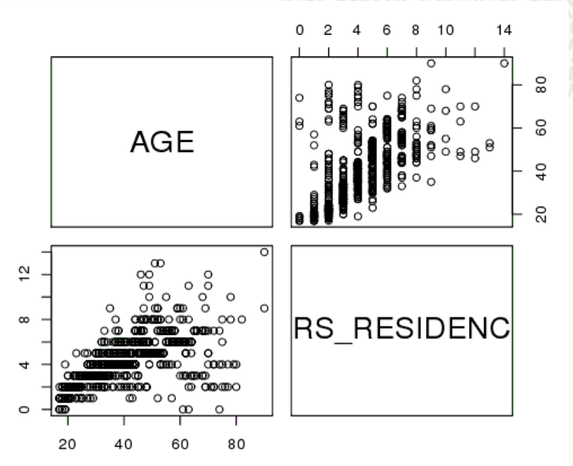
rqEval – invoking a simple R script

```
hist(NARROW[,"AGE"])
pairs(NARROW[,c("AGE","YRS_RESIDENCE")])
```






```
select *
  from table(rqTableEval(cursor(select AGE from NARROW), NULL,
                         'PNG',
                         'RQG$hist'));
select *
  from table(rqTableEval(cursor(select AGE, YRS_RESIDENCE from NARROW),
                         NULL,
                         'PNG',
                         'RQG$pairs'));
-- best viewed from SQL Developer
```

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OML4R-defined package and version function examples

Embedded R Function	Wraps R Function	Arguments	Return Values
RQ$R.Version	R.Version	None	R version-relevant info
RQ$getRversion	getRversion	None	R version number
RQ$installed.packages	Installed.packages	None	Package name, version number, package installation location, installed packages
RQ$packageVersion	packageVersion	Package name	Package version number

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Invoking a simple R script from R and SQL

```
select * from table(rqEval(NULL,
  'select cast(''a'' as varchar2(14)) "name", cast(''a''
as varchar2(50)) "value" from dual',
  'RQ$R.Version'));
```

```
ore.doEval(FUN.NAME="RQ$R.Version")
ore.doEval(FUN.NAME="RQ$getRversion")
ore.doEval(FUN.NAME="RQ$installed.packages")
ore.doEval(FUN.NAME="RQ$packageVersion",pkg="OREbase")

ore.scriptList(name="RQ$packageVersion",type="global")
```

```
R> ore.doEval(FUN.NAME="RQ$R.Version")
             name                                                value
1        platform                          x86_64-unknown-linux-gnu
2            arch                                             x86_64
3              os                                          linux-gnu
4          system                                 x86_64, linux-gnu
5          status                                               <NA>
6           major                                                  3
7           minor                                                0.1
8            year                                               <NA>
9           month                                               <NA>
10            day                                               <NA>
11        svn rev                                                -99
12       language                                                  R
13 version.string Oracle Distribution of R version 3.0.1  (--)
14       nickname                                       Good Sport
```

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Viewing contents of the R Script Repository

```
# List all user scripts
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
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

ore.sync(table = "RQ_SCRIPTS", schema = "SYS")
ore.attach(schema = "SYS")
row.names(RQ_SCRIPTS) <- RQ_SCRIPTS$NAME
RQ_SCRIPTS$NAME                      # List all scripts in SYS schema
RQ_SCRIPTS["RQ$packageVersion",]  # View script body
```

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Returning R statistical results as a DB table
A step-by-step example

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Step 1: invoke from command line, understand results

```
mod <- princomp(USArrests, cor = TRUE)
class(mod)
mod
dat <- ore.push(USArrests) # create ore.frame
```

```
R> mod <- princomp(USArrests, cor = TRUE)
R> class(mod)
[1] "princomp"
R> mod
Call:
princomp(x = USArrests, 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.
R> dat <- ore.push(USArrests)
```

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Step 2: wrap in function, invoke from ore.tableApply

```
res <- ore.tableApply(dat,
       function(dat) {
         princomp(dat, cor=TRUE)
       })
class(res)
res.local <- ore.pull(res)
class(res.local)
str(res.local)
res.local
res
```

```
R> res <- ore.tableApply(dat,
+ function(dat) {
+ princomp(dat, cor=TRUE)
+ })
R> class(res)
[1] "ore.object"
attr(,"package")
[1] "OREembed"
R> res.local <- ore.pull(res)
R> class(res.local)
[1] "princomp"
```

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Step 2: ...more results

```
R> str(res.local)
List of 7
$ sdev : Named num [1:4] 1.575 0.995 0.597 0.416
..- attr(*, "names")= chr [1:4] "Comp.1" "Comp.2" "Comp.3" "Comp.4"
$ loadings: loadings [1:4, 1:4] -0.536 -0.583 -0.278 -0.543 0.418 ...
..- attr(*, "dimnames")=List of 2
.. ..$ : chr [1:4] "Murder" "Assault" "UrbanPop" "Rape"
.. ..$ : chr [1:4] "Comp.1" "Comap.2" "Comp.3" "Comp.4"
$ center : Named num [1:4] 7.79 170.76 65.54 21.23
..- attr(*, "names")= chr [1:4] "Murder" "Assault" "UrbanPop" "Rape"
$ scale : Named num [1:4] 4.31 82.5 14.33 9.27
..- attr(*, "names")= chr [1:4] "Murder" "Assault" "UrbanPop" "Rape"
$ n.obs : int 50
$ scores : num [1:50, 1:4] -0.986 -1.95 -1.763 0.141 -2.524 ...
..- attr(*, "dimnames")=List of 2
.. ..$ : chr [1:50] "1" "2" "3" "4" ...
.. ..$ : chr [1:4] "Comp.1" "Comp.2" "Comp.3" "Comp.4"
$ call : language princomp(x = dat, cor = TRUE)
- attr(*, "class")= chr "princomp"
```

```
R> res.local
Call:
princomp(x = dat, 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.
R> res
Call:
princomp(x = dat, 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.
```

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Step 3: determine what results we really need

```
res <- ore.tableApply(dat,
    function(dat) {
      mod <- princomp(dat, cor=TRUE)
      dd <- dim(mod$loadings)
      ldgs <-
as.data.frame(mod$loadings[1:dd[1],1:dd[2]])
      ldgs$variables <- row.names(ldgs)
      ldgs
    })
class(res)
res
```

```
ore.create(USArrests,table="USARRESTS")
```

```
R> res <- ore.tableApply(dat,
+ function(dat) {
+ mod <- princomp(dat, cor=TRUE)
+ dd <- dim(mod$loadings)
+ ldgs <- as.data.frame(mod$loadings[1:dd[1],1:dd[2]])
+ ldgs$variables <- row.names(ldgs)
+ ldgs
+ })
R> class(res)
[1] "ore.object"
attr(,"package")
[1] "OREembed"
R> res
               Comp.1     Comp.2     Comp.3     Comp.4
variables
Murder    -0.5358995  0.4181809 -0.3412327  0.64922780 Murder
Assault   -0.5831836  0.1879856 -0.2681484 -0.74340748 Assault
UrbanPop -0.2781909 -0.8728062 -0.3780158  0.13387773
UrbanPop
Rape      -0.5434321 -0.1673186  0.8177779  0.08902432 Rape
```

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Step 4: create script in repository using SQL
(could create from R API as well)

```
begin
sys.rqScriptDrop(‘princomp.loadings');
sys.rqScriptCreate('princomp.loadings',
      'function(dat) {
        mod <- princomp(dat, cor=TRUE)
        dd <- dim(mod$loadings)
        ldgs <- as.data.frame(mod$loadings[1:dd[1],1:dd[2]])
        ldgs$variables <- row.names(ldgs)
        ldgs
      }');
end;
/
```

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Step 5: invoke from SQL select statement

```
select *
from table(rqTableEval( cursor(select * from USARRESTS),
                        NULL,
                       'select 1 as "Comp.1", 1 as "Comp.2", 1 as "Comp.3", 1 as
"Comp.4", cast(''a'' as varchar2(12)) "variables" from dual',
                        'RQUSER.princomp.loadings'));
```

***IMPORTANT**: As of OML4 1.5, if a script name contains a '.' you will need to prefix the name with the user schema name where it was created. Otherwise it will not be found. Do not add this name upon creation, however.*

To avoid this, simply do not use '.' in script names.

```
SQL> select *
from table(rqTableEval( cursor(select * from USARRESTS),
                        NULL,
                       'select 1 as "Comp.1", 1 as
"Comp.2", 1 as "Comp.3", 1 as "Comp.4", cast(''a'' as
varchar2(12)) "variables" from dual',
                        'RQUSER.princomp.loadings'));
  2    3    4    5
    Comp.1     Comp.2     Comp.3     Comp.4 variables
---------- ---------- ---------- ---------- ------------
-.53589947 .418180865 -.34123273 .649227804 Murder
-.58318363 .187985604 -.26814843 -.74340748 Assault
-.27819087 -.87280619 -.37801579 .133877731 UrbanPop
-.54343209 -.16731864 .817777908 .089024323 Rape
```

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Summary

Execute user-defined R functions from SQL for applications and operational systems

Control and secure R code that runs in Oracle Database

Use data- and task-parallelism for user-defined R functions

- Interface function enable parallelism using multiple database R engines
- Parallel simulations

Rq*Eval enables:

- Rich XML and PNG image output for integration with applications, dashboards and any tool or system that can consume such data
- R data.frame results returned as query rowsets, i.e., tables

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Thank You

Mark Hornick
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