ORACLE

Session 1: Introduction to Oracle's R Technologies

With Oracle Machine Learning

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Safe harbor statement

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Agenda

1. What is R
2. Oracle Machine Learning overview
3. Oracle R Distribution
4. ROracle Package
5. Oracle Machine Learning for Spark
6. Oracle Machine Learning for R
7. Summary

What is R?

R is an Open Source scripting language and environment for statistical computing and graphics http://www.R-project.org/

Started in 1994 as an Alternative to SAS, SPSS and other proprietary Statistical Environments

An integrated suite of software facilities for data manipulation, calculation and graphical display

Millions of R users worldwide

- Widely taught in Universities
- Many Corporate Analysts and Data Scientists know and use R

Thousands of open sources packages to enhance productivity such as:

- Bioinformatics with R
- Spatial Statistics with R
- Financial Market Analysis with R
- Linear and Non Linear Modeling

Topics

Bayesian	Bayesian Inference
ChemPhys	Chemometrics and Computational Physics
ClinicalTrials	Clinical Trial Design, Monitoring, and Analysis
Cluster	Cluster Analysis & Finite Mixture Models
Databases	Databases with R
DifferentialEquations	Differential Equations
Distributions	Probability Distributions
Econometrics	Econometrics
Environmetrics	Analysis of Ecological and Environmental Data
ExperimentalDesign	Design of Experiments (DoE) & Analysis of Experimental Data
ExtremeValue	Extreme Value Analysis
Finance	Empirical Finance
FunctionalData	Functional Data Analysis
Genetics	Statistical Genetics
Graphics	Graphic Displays & Dynamic Graphics & Graphic Devices & Visualization
HighPerformanceComputing	High-Performance and Parallel Computing with R
Hydrology	Hydrological Data and Modeling
MachineLearning	Machine Learning & Statistical Learning
MedicalImaging	Medical Image Analysis
MetaAnalysis	Meta-Analysis
MissingData	Missing Data
ModelDeployment	Model Deployment with R
Multivariate	Multivariate Statistics
NaturalLanguageProcessing	Natural Language Processing
NumericalMathematics	Numerical Mathematics
OfficialStatistics	Official Statistics & Survey Methodology
Optimization	Optimization and Mathematical Programming
Pharmacokinetics	Analysis of Pharmacokinetic Data
Phylogenetics	Phylogenetics, Especially Comparative Methods
Psychometrics	Psychometric Models and Methods
ReproducibleResearch	Reproducible Research
Robust	Robust Statistical Methods
SocialSciences	Statistics for the Social Sciences
Spatial	Analysis of Spatial Data
SpatioTemporal	Handling and Analyzing Spatio-Temporal Data
Survival	Survival Analysis
TeachingStatistics	Teaching Statistics
TimeSeries	Time Series Analysis
Tracking	Processing and Analysis of Tracking Data
WebTechnologies	Web Technologies and Services
gR	gRaphical Models in R

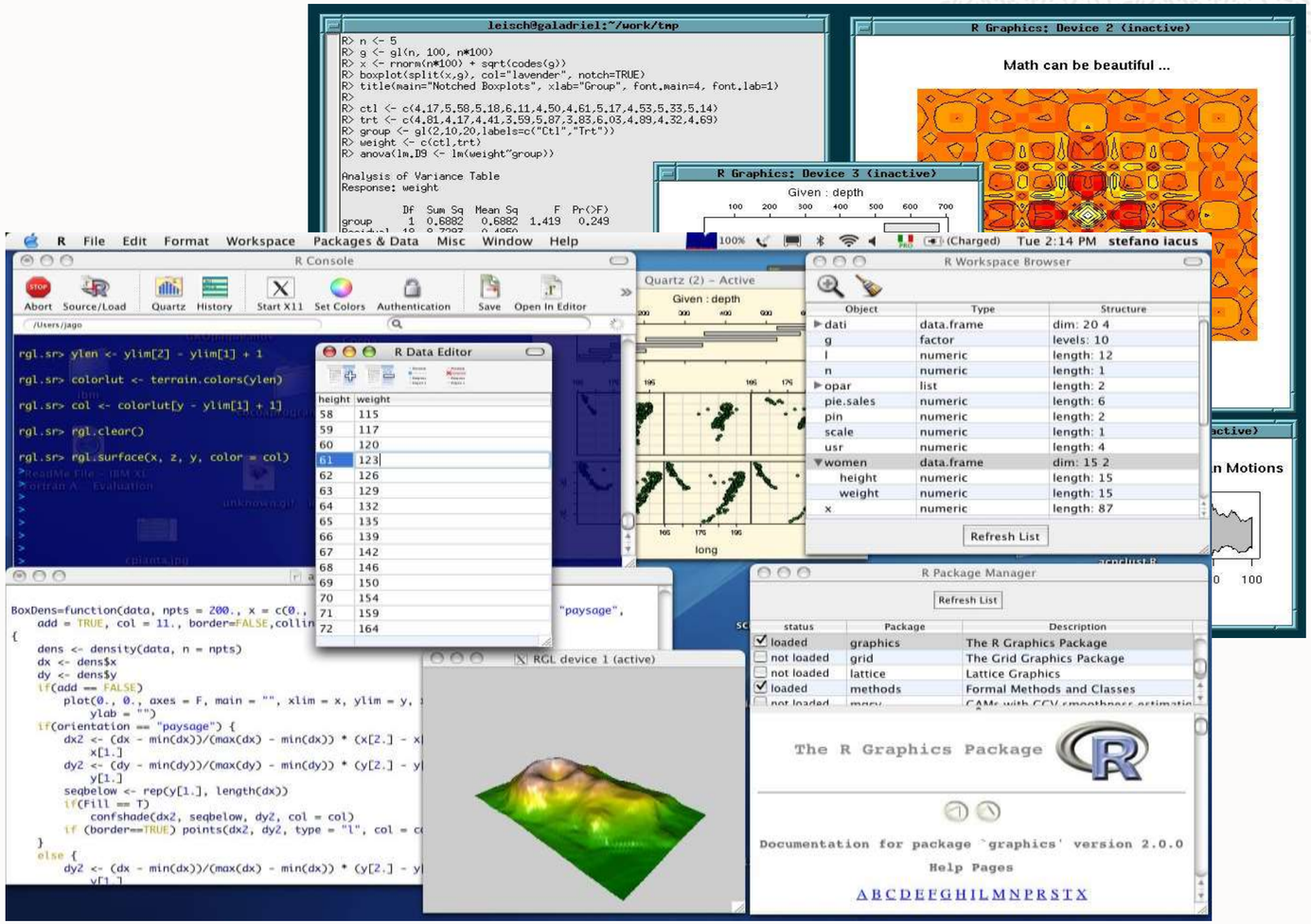
Why data scientists | statisticians | data analysts use R

R is a statistics language similar to Base SAS or SPSS statistics

R environment is ..

- Powerful
- Extensible
- Graphical
- Extensive statistics
- OOTB functionality with many ‘knobs’ but smart defaults
- Ease of installation and use
- ***Free***

http://cran.r-project.org/



Analytic Pain Points

It takes too long to get my data or to get the ‘right’ data

I can’t analyze or mine all of my data – it has to be sampled

Putting analytics/predictive models and results into production is ad hoc and complex

Recoding R or other models into SQL, C, or Java takes time and is error prone

Our company is concerned about data security, backup and recovery

We need to build 10s of thousands of models fast to meet business objectives

See the blog series at https://blogs.oracle.com/R/entry/addressing_analytic_pain_points

Oracle Machine Learning

Oracle Machine Learning differentiators

Work directly with data in Database and Hadoop

Eliminate need to request extracts from IT/DBA – immediate access to database and Hadoop data

Process data where they reside – minimize or eliminate data movement

Scalability and Performance

Use parallel, distributed algorithms that scale to big data on Oracle Database

Leverage Exadata-class machines to build models on billions of rows of data

Ease of deployment

Using Oracle Database, place **R, Python, and SQL scripts** immediately in production (no need to recode)

Use production quality infrastructure without custom plumbing or extra complexity

Process support

Maintain and ensure data security, backup, and recovery using existing processes

Store, access, manage, and track analytics objects (models, scripts, workflows, data) in Oracle Database

ORACLE APPLICATIONS

Oracle Machine Learning

OML4SQL
SQL API

OML Notebooks
with Apache Zeppelin on Autonomous Database

OML4R
R API

Oracle Data Miner
Oracle SQL Developer extension

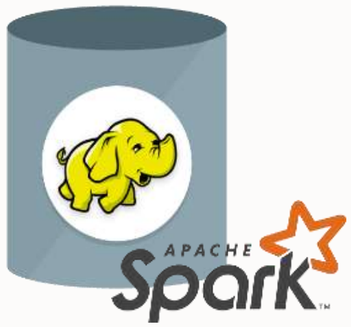
OML4Py*
Python API

OML4Spark
R API on Big Data

OML AutoML UI*
Code-free AutoML interface on Autonomous Database

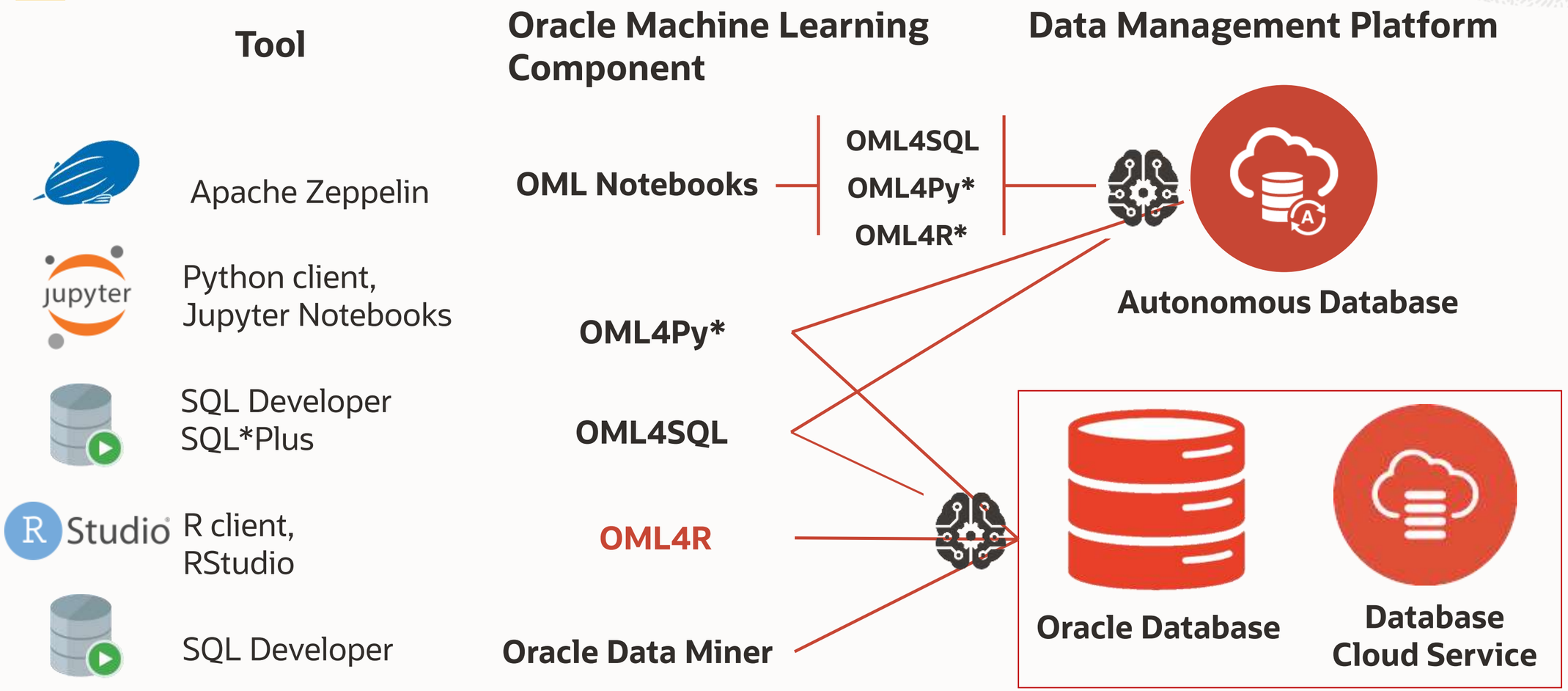
OML Services*
Model Deployment and Management, Cognitive Text

ORACLE APPLICATIONS



* Coming soon

Oracle Machine Learning interfaces to Oracle Database



*Coming soon

Oracle Machine Learning Algorithms and Analytics

Classification
- Naïve Bayes
- Logistic Regression (GLM)
- Decision Tree
- Random Forest
- Neural Network
- Support Vector Machine (SVM)
- Explicit Semantic Analysis
- *XGBoost**

Anomaly Detection
- One-Class SVM
- *MSET-SPRT**

Clustering
- Hierarchical K-Means
- Hierarchical O-Cluster
- Expectation Maximization (EM)

Time Series
- Forecasting - Exponential Smoothing
- Includes popular models
  e.g. Holt-Winters with trends, seasonality, irregularity, missing data

Regression
- Linear Model
- Generalized Linear Model (GLM)
- Support Vector Machine (SVM)
- Stepwise Linear regression
- Neural Network
- LASSO
- *XGBoost**

Attribute Importance
- Minimum Description Length
- Principal Component Analysis (PCA)
- Unsupervised Pair-wise KL Div
- CUR decomposition for row & AI

Association Rules
- A priori/ market basket

Predictive Queries
- Predict, cluster, detect, features

SQL Analytics
- SQL Windows
- SQL Patterns
- SQL Aggregates

Feature Extraction
- Principal Comp Analysis (PCA)
- Non-negative Matrix Factorization
- Singular Value Decomposition (SVD)
- Explicit Semantic Analysis (ESA)

Row Importance
- CUR Decomposition

Ranking
- *XGBoost**

Text Mining Support
- Algorithms support text columns
- Tokenization and theme extraction
- Explicit Semantic Analysis (ESA)

Statistical Functions
- min, max, median, stdev, t-test, F-test, Pearson's, Chi-Sq, ANOVA, etc.

R and Python Packages
- Third-party R and Python Packages through Embedded Execution
- Spark MLlib algorithm integration

** New in 20c*

Oracle Machine Learning Notebooks

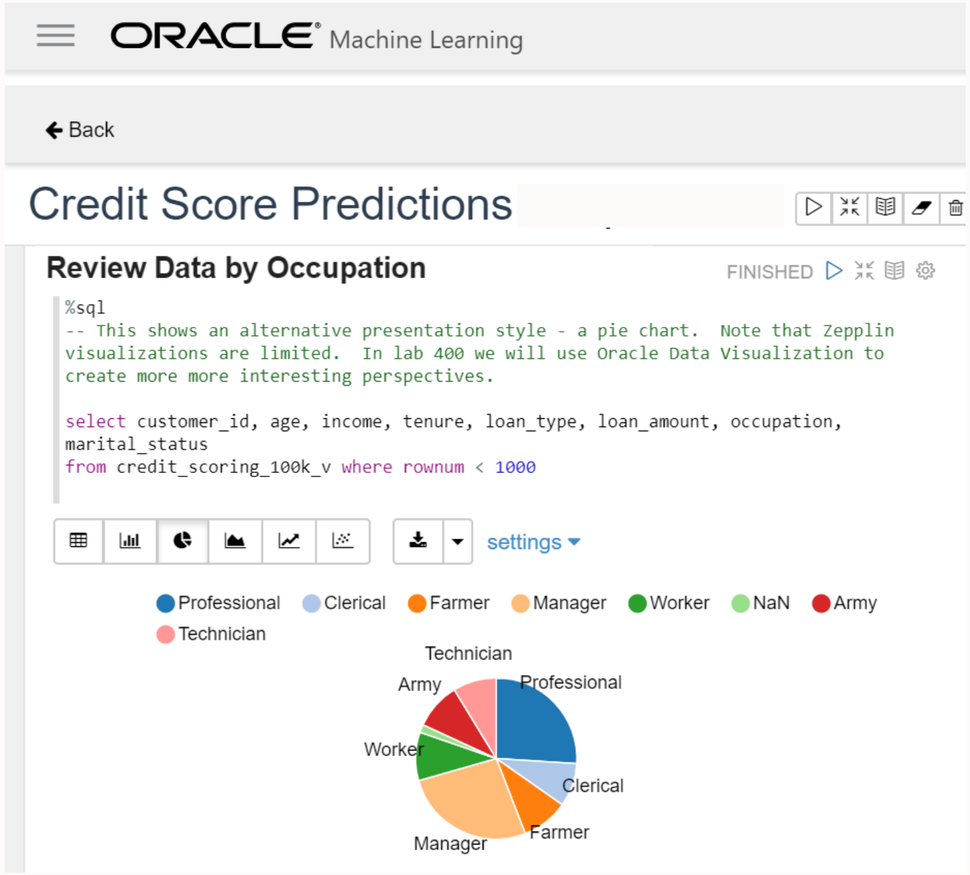
Autonomous Database as a Data Science Platform

Collaborative UI

- Based on Apache Zeppelin
- Supports data scientists, data analysts, application developers, DBAs with SQL and Python
- Easy sharing of notebooks and templates
- Permissions, versioning, and execution scheduling

Included with Autonomous Database

- Automatically provisioned, managed, backed up
- In-database algorithms and analytics functions
- Explore and prepare, build and evaluate models, score data, deploy solutions
- Soon to be augmented with R



Oracle Machine Learning for SQL

Empower SQL users with immediate access to ML included with Oracle Database and Oracle Autonomous Database

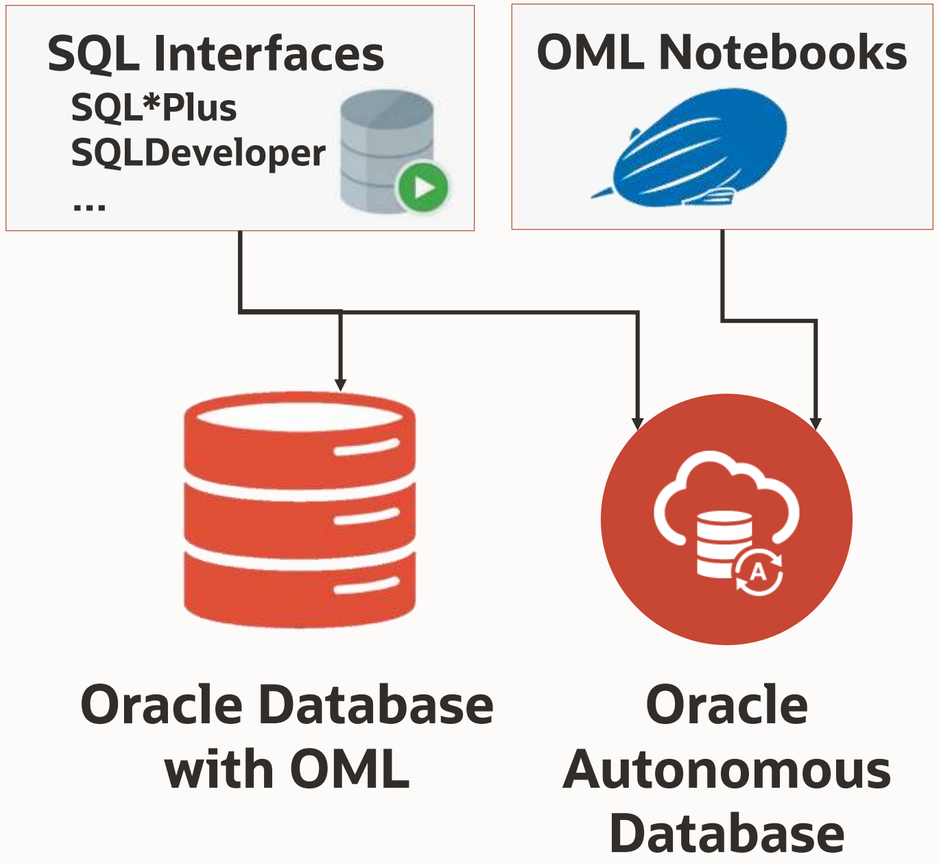
In-database, parallelized, distributed algorithms

- No extracting data to separate ML engine
- Fast and scalable
- Batch and real-time scoring
- Explanatory prediction details

ML models as first-class database objects

- Access control via permissions
- Audit user actions
- Export / import models across databases

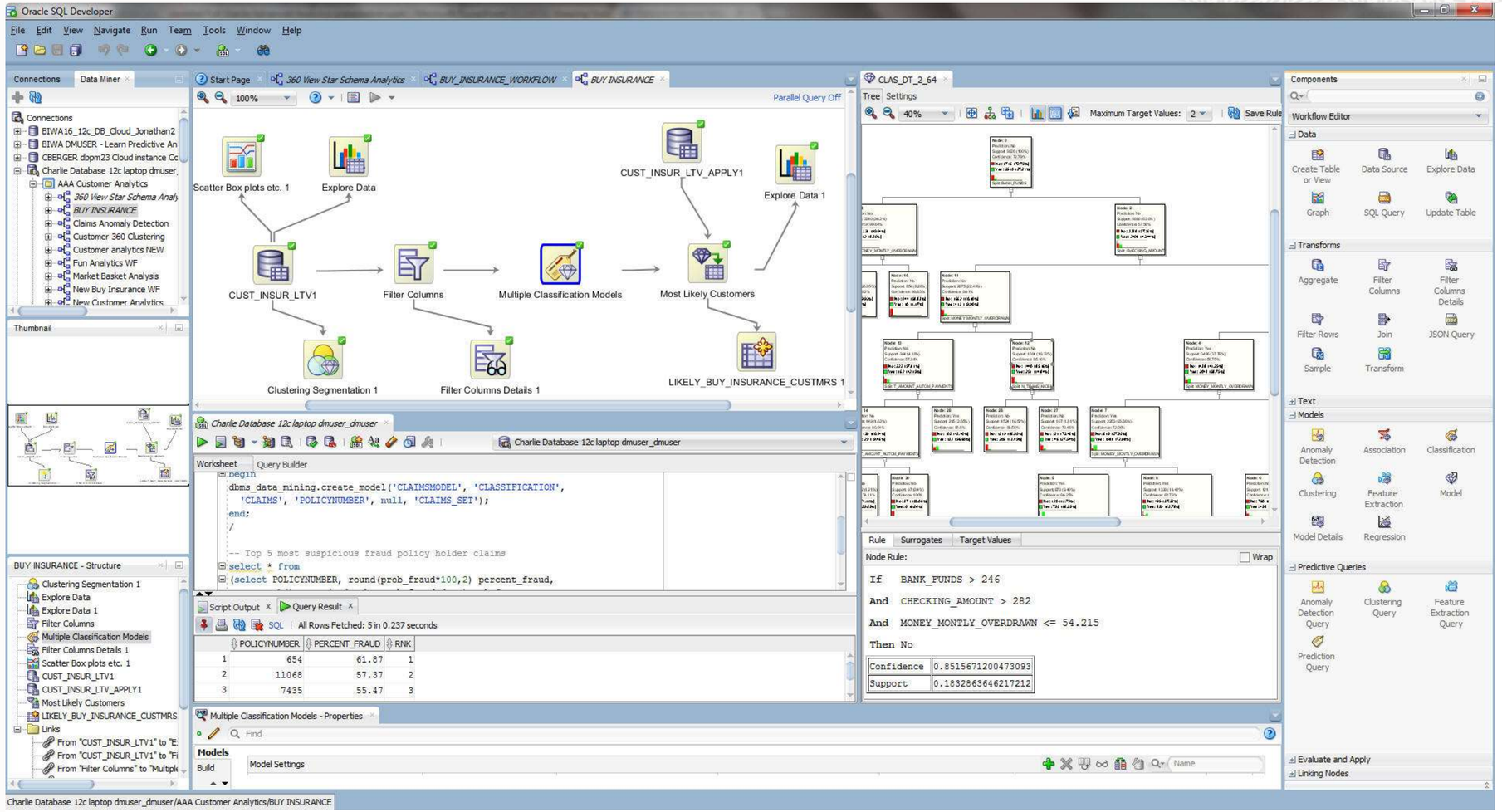
Leverage ML across Oracle stack



Oracle Data Miner User Interface

Create analytical workflows – productivity tool for data scientists – enables citizen data scientists

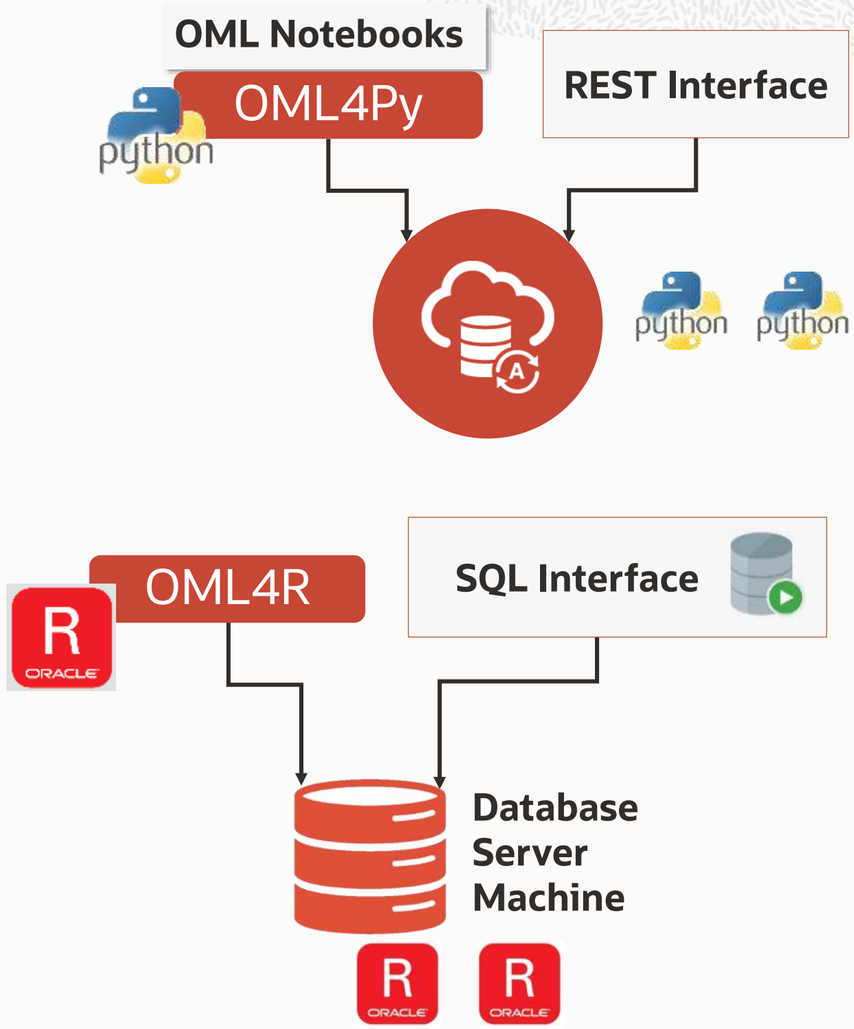
- SQL Developer Extension for Oracle Database on premise and DBCS
- Automates typical data science steps
- Easy to use drag-and-drop interface
- Analytical workflows quickly defined and shared
- Wide range of algorithms and data transformations
- Generate SQL code for immediate deployment



Oracle Machine Learning for R and Python

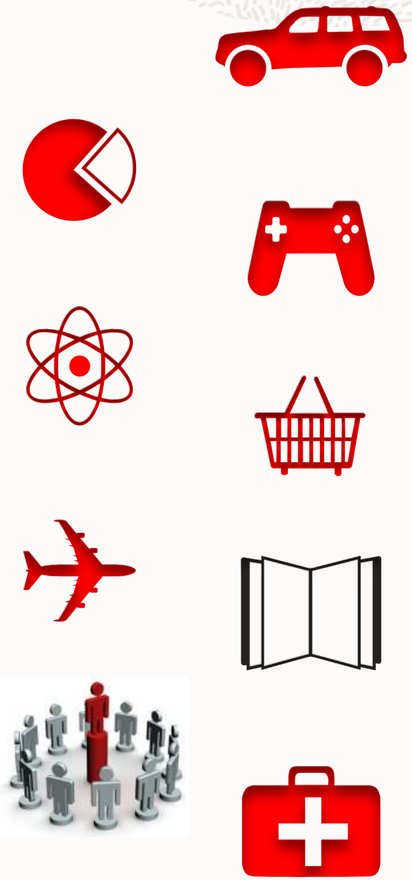
Empower data scientists with open source environments

- Oracle Database as HPC environment
- In-database parallelized and distributed machine learning algorithms
- Manage scripts and objects in Oracle Database
- Integrate results into applications and dashboards via SQL or REST
- OML4Py automated machine learning



Sample Use cases

Detect fraud in customer transactions, insurance claims
Identify which patients are at risk of developing certain conditions
Target the right customer with the right offer
Discover hidden customer segments
Forecast customer demand for a product or service
Find most profitable selling opportunities
Anticipate and preventing customer churn
Identify customers likely to churn and why
Security and suspicious activity detection
Understand sentiments in customer conversations
Understand influencers in social networks
Predict credit risk



Oracle's R Technologies

Supporting R, Oracle Database, and Big Data Appliance/Hadoop

Oracle R Distribution

ROracle

Software available to R Community for free

Oracle Machine Learning for R

Included with Oracle Database license and Oracle Database Cloud Service

Oracle Machine Learning for Spark

Component of the Big Data Connectors Software Suite and Big Data Service

Oracle R Distribution

Oracle R Distribution

+

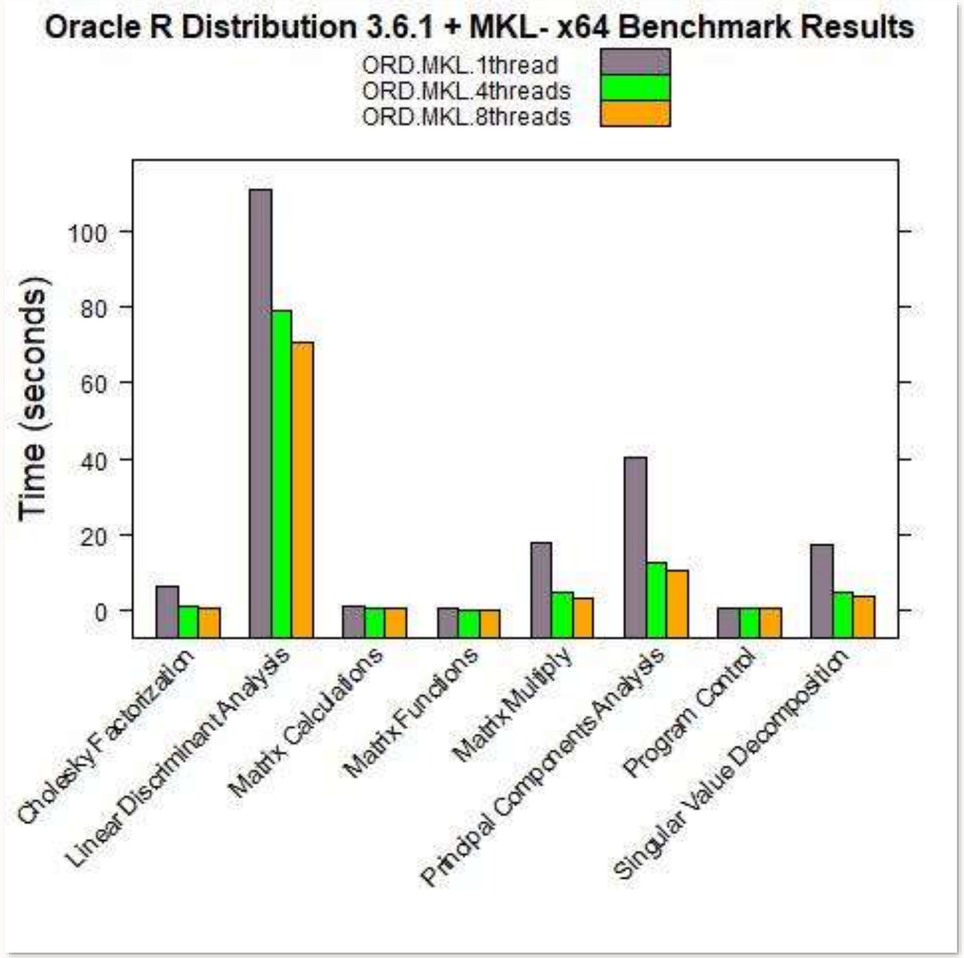
Ability to dynamically load
Intel Math Kernel Library
AMD Core Math Library
Solaris Sun Performance Library

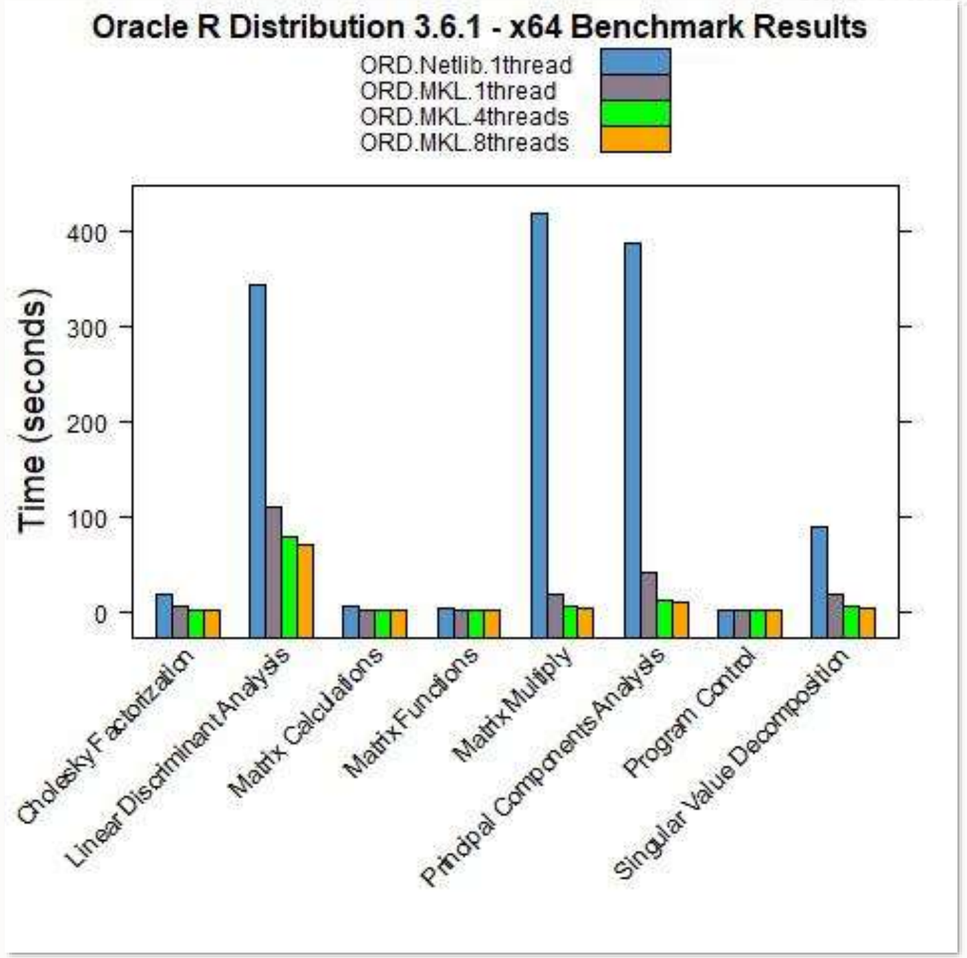
+

Oracle Support

- An Oracle-Supported Redistribution of Open Source R, now R 3.6.1
- Enhanced linear algebra performance via dynamically loaded libraries
- Improve performance at client and database for embedded R execution
- Enterprise support for customers of Oracle Advanced Analytics option, Big Data Appliance, and Oracle Linux
- Free download
- Oracle contributes bug fixes and enhancements to open source R

ORD Performance with MKL





ROracle Package

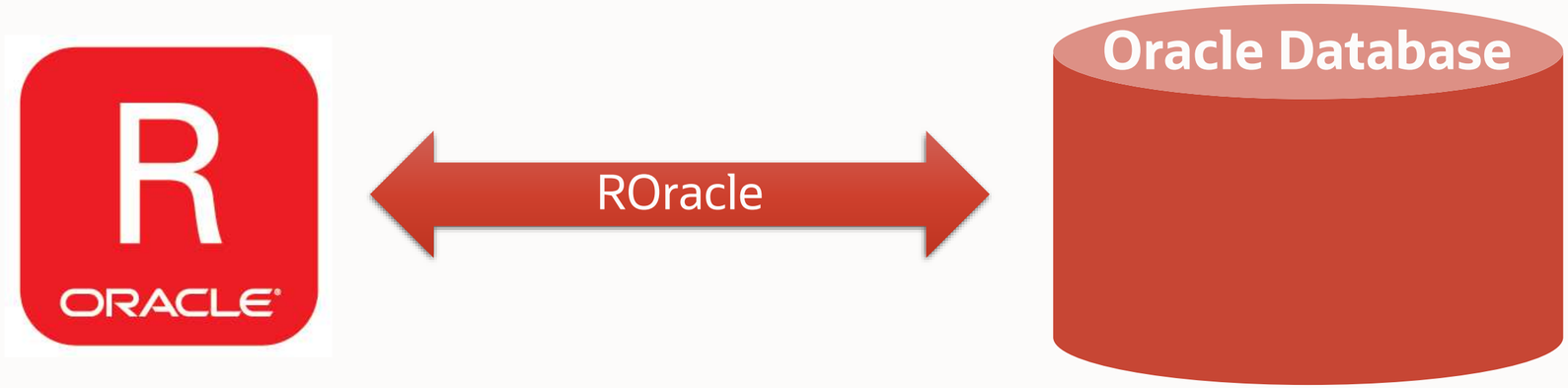
ROracle

R package enabling scalable and performant connectivity to Oracle Database

- Open source, publicly available on CRAN
- Oracle is maintainer

Oracle Database Interface (DBI) for R

- Re-implemented and optimized driver based on OCI
- Execute SQL statements from R interface
- Enables transactional behavior for insert, update, and delete



ROracle Example – enabling transactional behavior

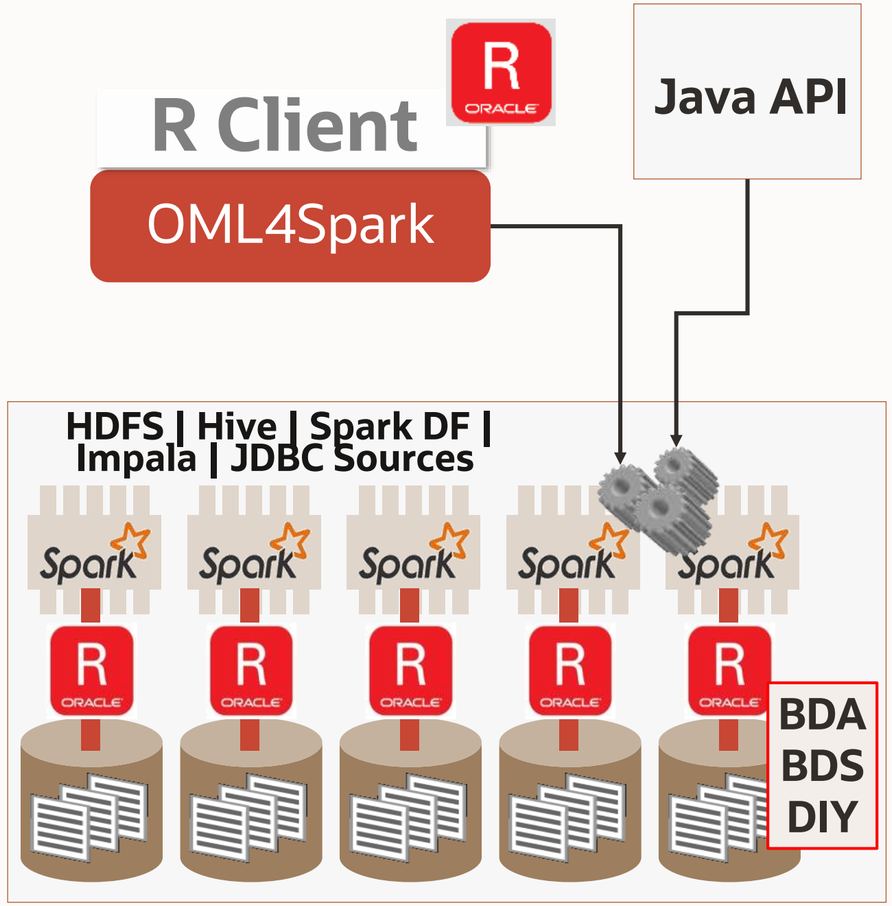
```
drv <- dbDriver("Oracle")
con <- dbConnect(drv, username = "scott", password = "tiger")
dbReadTable(con, "EMP")
rs <- dbSendQuery(con, "delete from emp where deptno = 10")

dbReadTable(con, "EMP")
if(dbGetInfo(rs, what = "rowsAffected") > 1){
   warning("dubious deletion -- rolling back transaction")
   dbRollback(con)
}
dbReadTable(con, "EMP")
```

Oracle Machine Learning for Spark (OML4Spark)

Oracle Machine Learning for Spark

R Language API Component to Oracle Big Data Connectors

- Leverage Spark 2 environment for powerful data preparation and machine learning
- Use data across range of Data Lake sources
- Achieve scalability and performance using full Hadoop cluster
- Parallel and distributed ML algorithms from native and Spark MLlib implementations



Oracle Machine Learning for Spark

R Language API Component to Oracle Big Data Connectors

Transparency layer

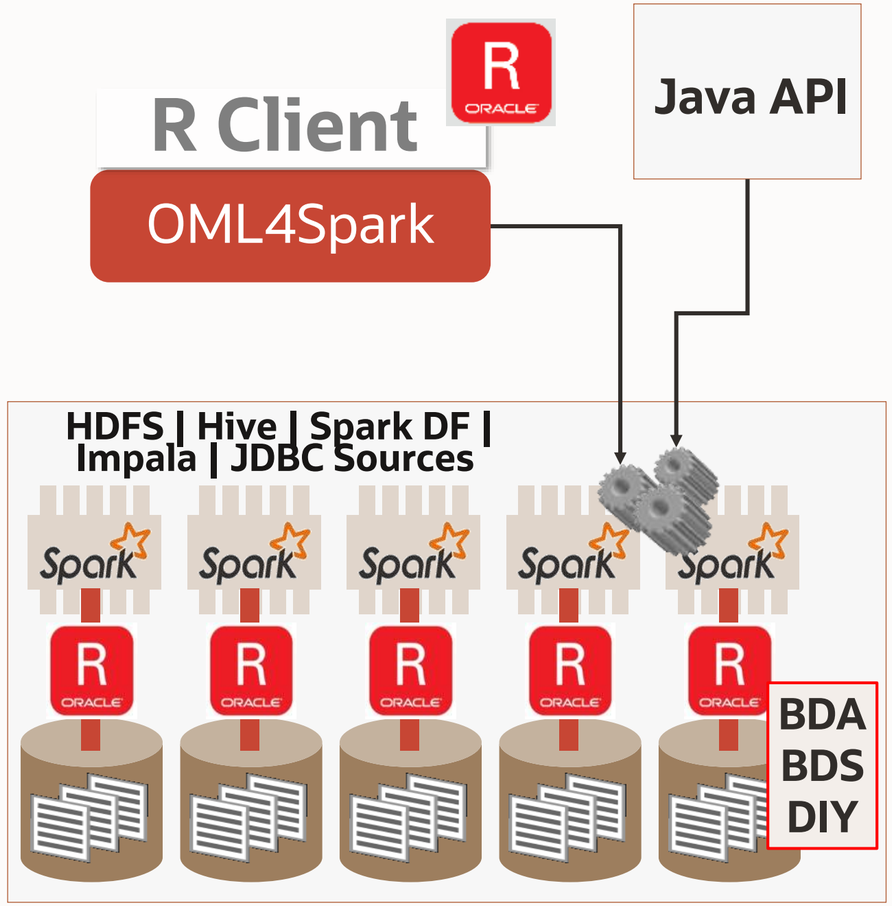
- Proxy objects reference data from file system, HDFS, Hive, Impala, Spark DataFrame and JDBC sources
- Overloaded R functions translate functionality to native language, e.g., HiveQL for HIVE and Impala
- Users manipulate data via standard R syntax

Parallel, distributed machine learning algorithms

- Scalability and performance leveraging full Hadoop cluster
- Spark-based custom LM, GLM, NN, K-Means plus Spark MLlib
- Use expressive R Formula specification

Compute framework with custom R mappers/reducers

- Data-parallel and task-parallel execution
- Allows for open source CRAN packages run on Cluster Nodes



OML4Spark Performance

Logistic Regression (GLM)

Data fits in memory

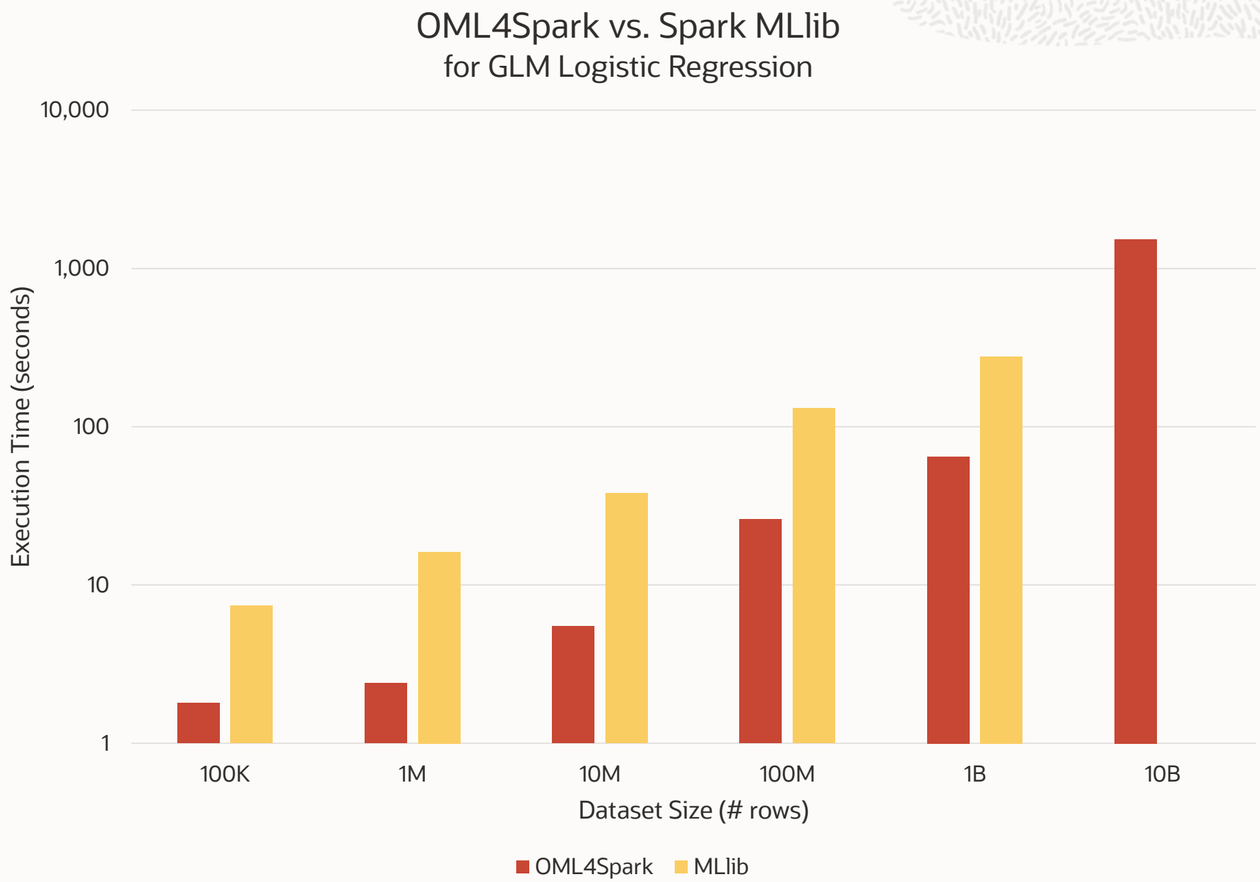
- Up to 7x faster than Spark MLlib

Data cannot fit memory

- Able to solve a 10B row model

Benchmark environment

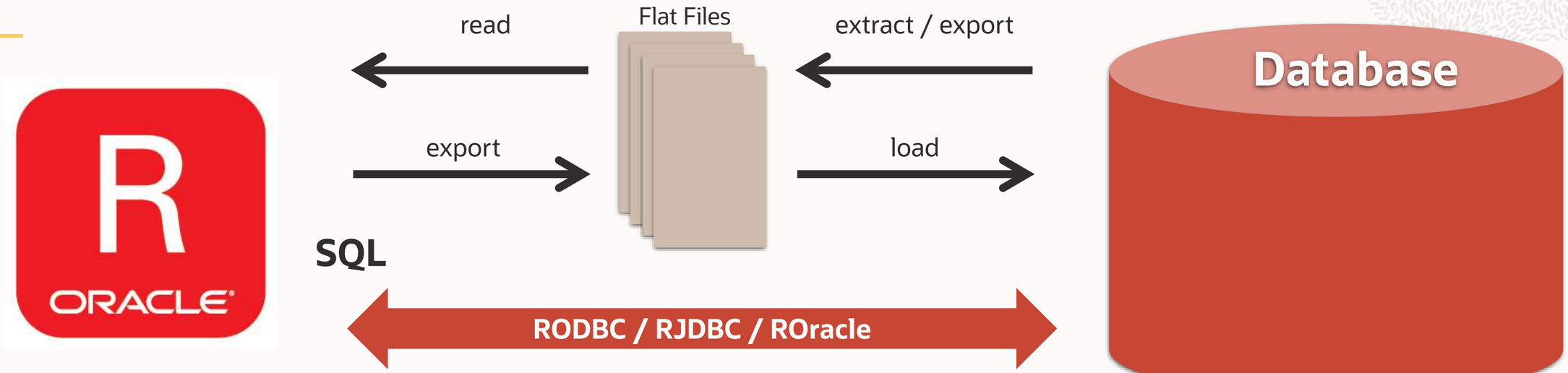
- ORAAH 2.8.0
- Big Data Appliance X7-2
- 6 Nodes, 256GB of RAM per Node



Formula: cancelled ~ distance + origin + dest + as.factor(month) + as.factor(year) + as.factor(dayofmonth) + as.factor(dayofweek) + as.factor(flightnum)

Oracle Machine Learning for R (OML4R)

Traditional R and Database Interaction



R script
cron job

Access latency

Paradigm shift: R → SQL → R

Memory limitation – data size, call-by-value

Single threaded

Ad hoc production deployment

Issues for backup, recovery, security

Oracle Machine Learning for R

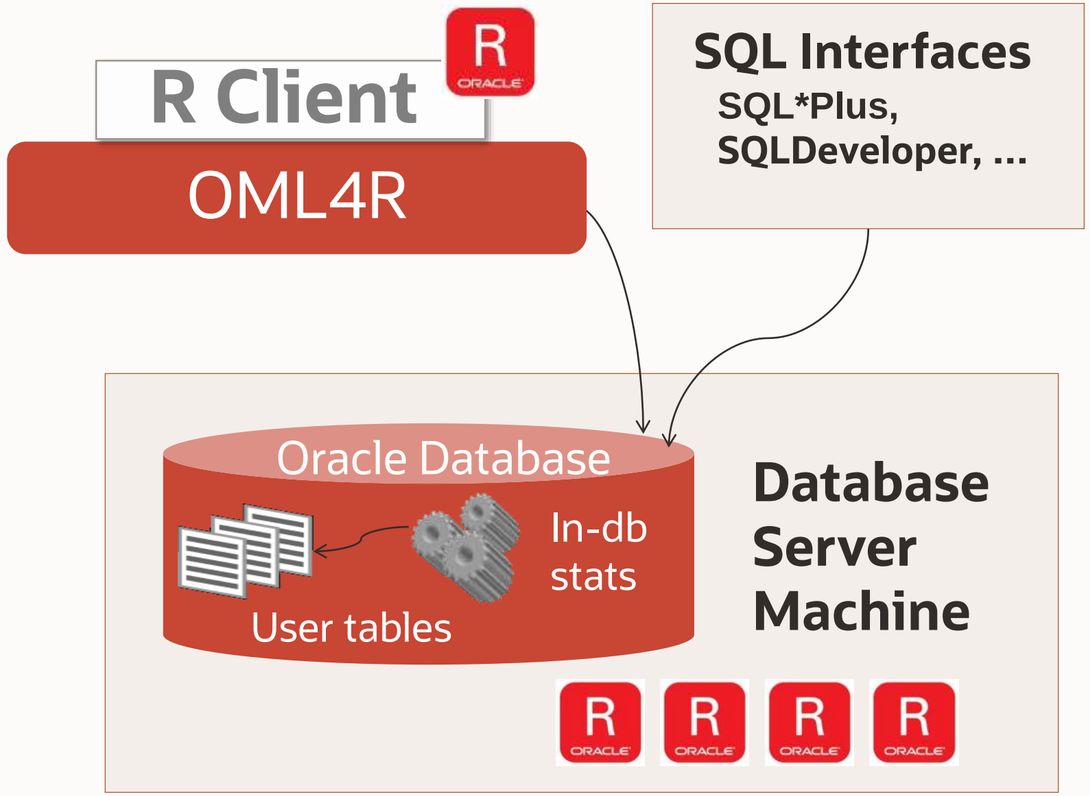
Component of Oracle Database

Use Oracle Database as HPC environment

Use in-database parallel and distributed machine learning algorithms

Manage R scripts and R objects in Oracle Database

Integrate R results into applications and dashboards via SQL



Oracle Machine Learning for R

Component of Oracle Database

Transparency layer

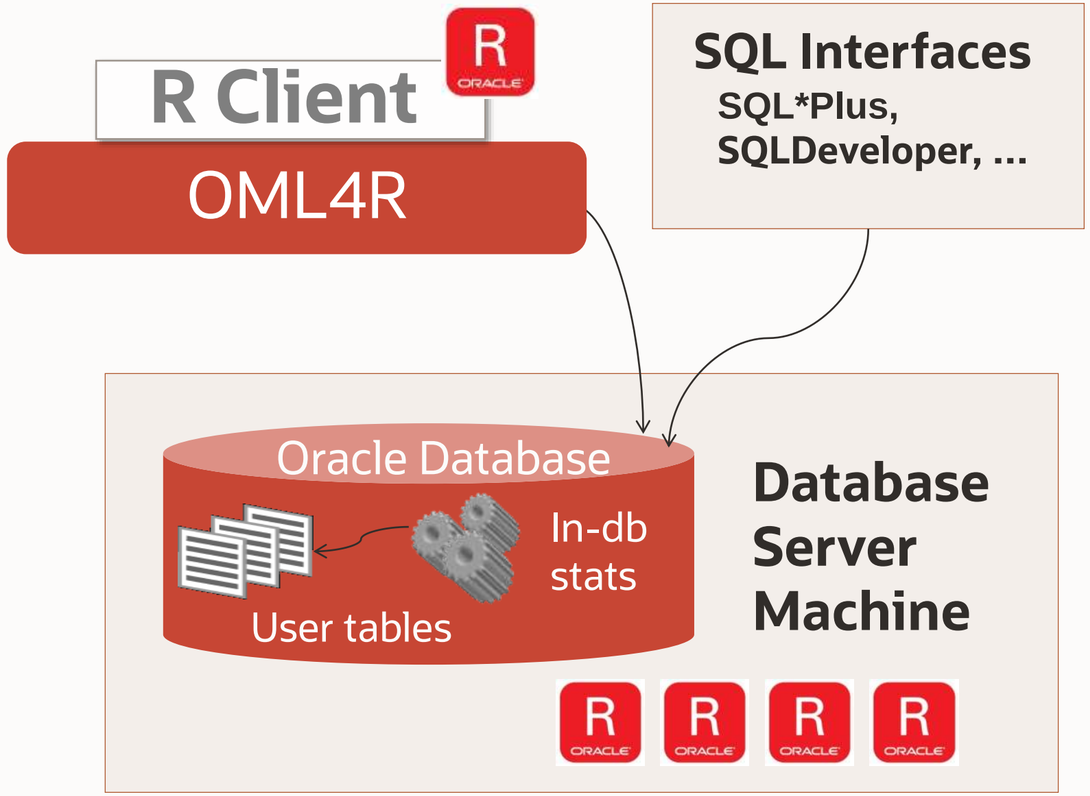
- Leverage proxy objects so data remains in database
- Overload R functions translating functionality to SQL
- Use standard R syntax to manipulate database data

Parallel, distributed machine learning algorithms

- Scalability and performance
- Exposes in-database algorithms from OML4SQL
- Additional R-based algorithms executing at database server

Embedded R execution

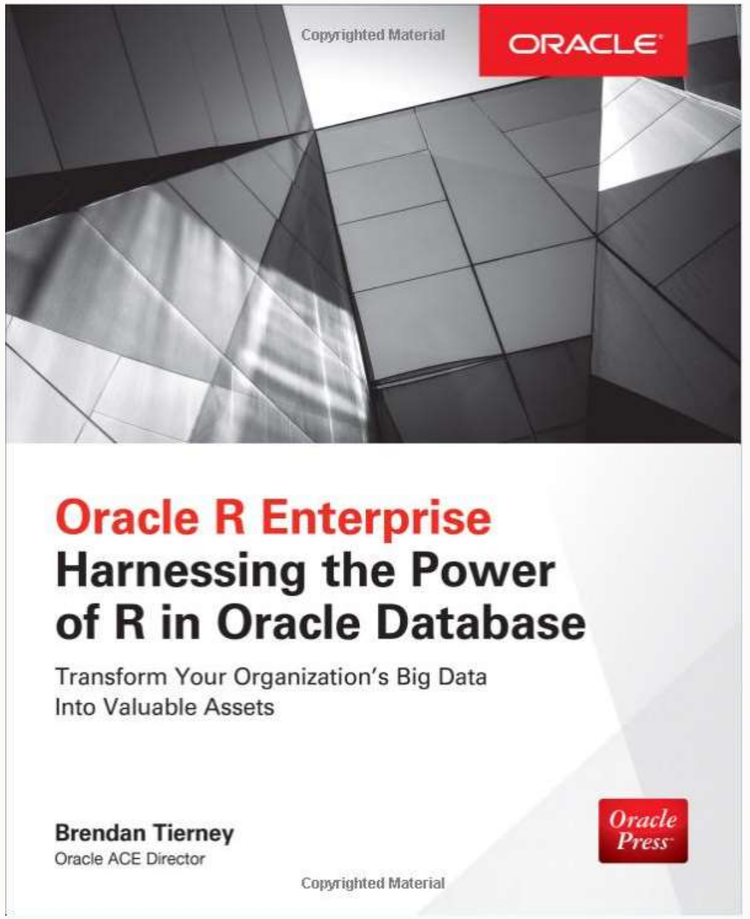
- Manage and invoke R scripts from Oracle Database
- Data-parallel, task-parallel, and non-parallel execution
- Use open source CRAN packages



Book on Oracle R Enterprise (OML4R)

Available on Amazon

[Oracle R Enterprise
Harnessing the Power of R in Oracle Database: Transform Your Organization's Big Data Into Valuable Assets]



OML4R Algorithms

…plus open source R packages for algorithms in combination with embedded R data- and task-parallel execution

Classification

- Decision Tree
- Logistic Regression
- Naïve Bayes
- Support Vector Machine
- RandomForest

Regression

- Linear Model
- Generalized Linear Model
- Multi-Layer Neural Networks
- Stepwise Linear Regression
- Support Vector Machine

Clustering

- Hierarchical k-Means
- Orthogonal Partitioning
- Expectation Maximization

Attribute Importance

- Minimum Description Length

Anomaly Detection

- 1 Class Support Vector Machine

Market Basket Analysis

- Apriori – Association Rules

Feature Extraction

- Nonnegative Matrix Factorization
- Principal Component Analysis
- Singular Value Decomposition
- Explicit Semantic Analysis

Time Series

- Single Exponential Smoothing
- Double Exponential Smoothing

Supports automatic data preparation, partitioned model ensembles, integrated text mining

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

The aggregate() function has been overloaded to accept ORE frames
aggregate() transparently switches between code that works with standard R data.frames and ore.frames

Returns an ore.frame

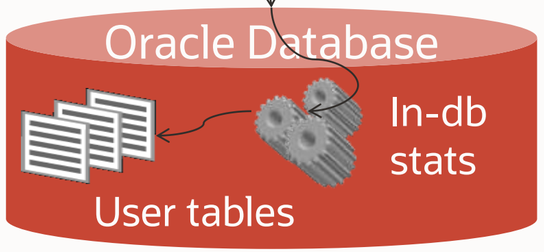
R user on desktop

Client R Engine

Transparency Layer

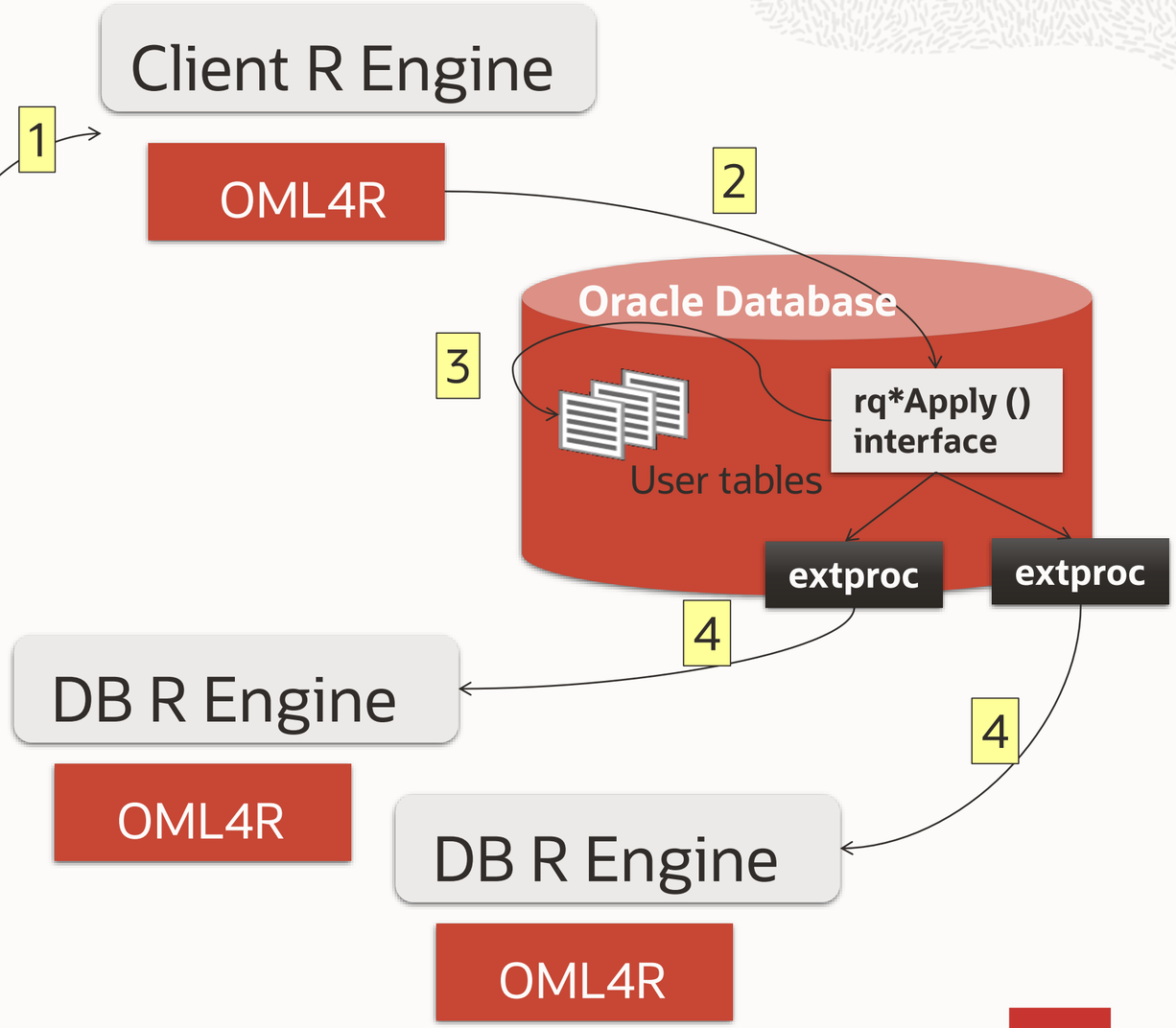
OML4R

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



ore.groupApply – partitioned data flow

```
modList <- ore.groupApply(
    X=ONTIME_S,
    INDEX=ONTIME_S$DEST,
    function(dat) {
       lm(ARRDELAY ~ DISTANCE + DEPDELAY, dat)
    });
summary(modList$BOS) ## return model for Boston
```

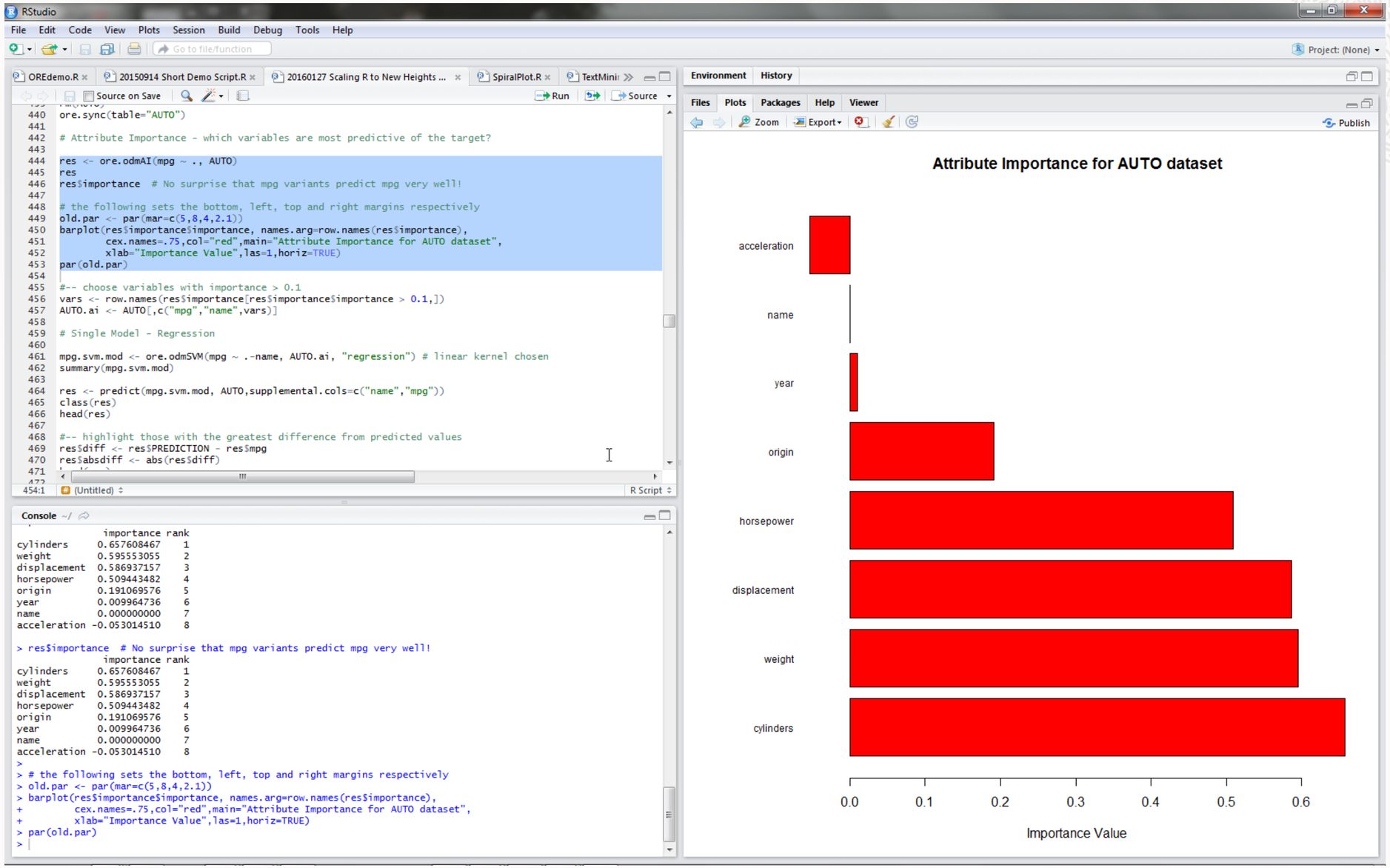


Also includes

- ore.doEval
- ore.tableApply
- ore.rowApply
- ore.indexApply

Select important predictors with ore.odmAI

In-database processing eliminates moving data



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 "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 "ore.connect",
                  'myDatastore' as "datastore_name" from dual),
    'select ARRDELAY, DISTANCE, DEPDELAY, 1 PRED from ontime_s',
    'Example3'))
order by 1, 2, 3;
```

Statistics via R Interface

Special Functions

- Gamma function
- Natural logarithm of the Gamma function
- Digamma function
- Trigamma function
- Error function
- Complementary error function

Tests

- Chi-square, McNemar, Bowker
- Simple and weighted kappas
- Cochran-Mantel-Haenzel correlation
- Cramer's V
- Binomial, KS, t, F, Wilcox

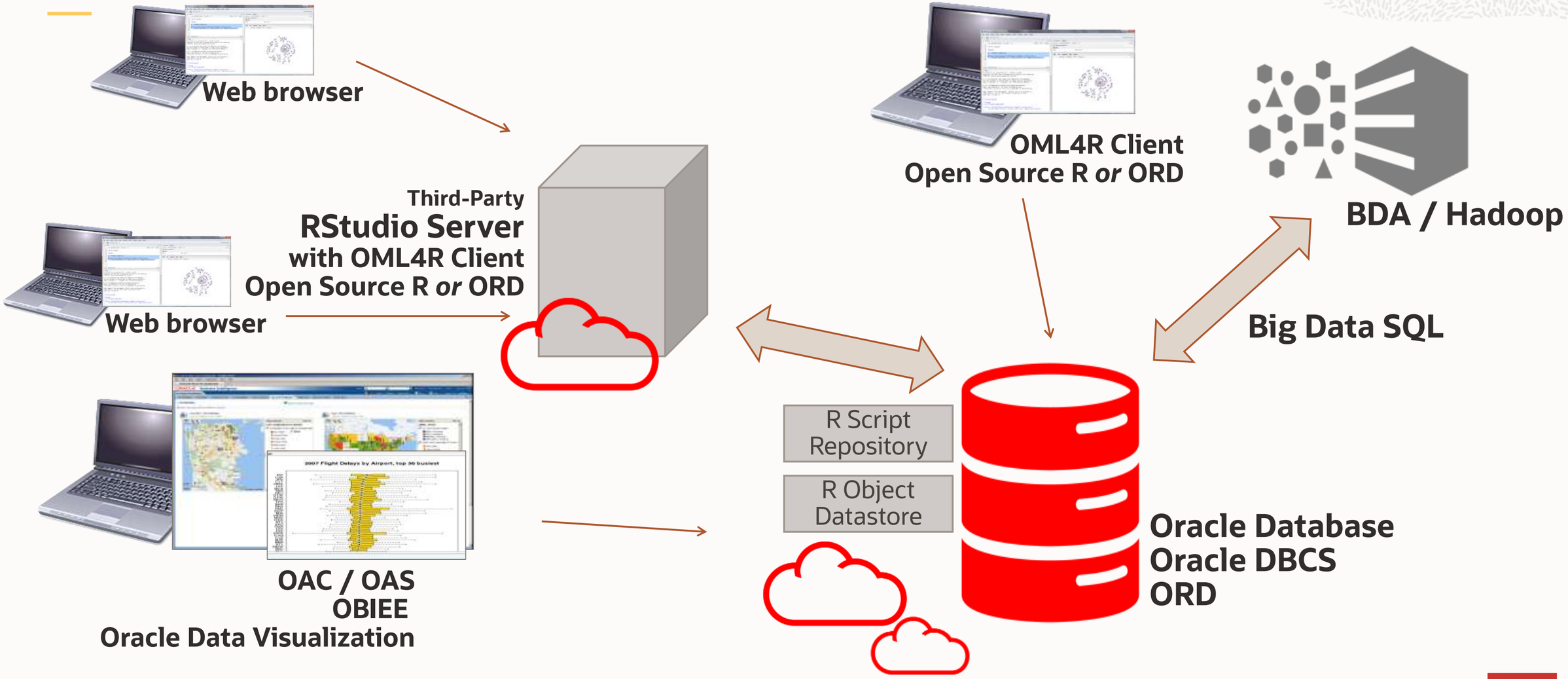
Base SAS equivalents

- Freq, Summary, Sort
- Rank, Corr, Univariate

Density, Probability, and Quantile Functions

- Beta distribution
- Binomial distribution
- Cauchy distribution
- Chi-square distribution
- Exponential distribution
- F-distribution
- Gamma distribution
- Geometric distribution
- Log Normal distribution
- Logistic distribution
- Negative Binomial distribution
- Normal distribution
- Poisson distribution
- Sign Rank distribution
- Student's t distribution
- Uniform distribution
- Weibull distribution
- Density Function
- Probability Function
- Quantile

Oracle Machine Learning for R deployment architecture options



Summary

Oracle supports interfaces for SQL, R, Python, and a no-code UI for in-database machine learning

Oracle enables R users with advanced analytics on Big Data

- Oracle Database
- Big Data Appliance and Cloudera/Hortonworks clusters with Oracle Machine Learning for Spark

Oracle's R technologies extend open source tools for Enterprise use

- Data analysis, exploration, and machine learning
- Simplified application development
- Production deployment

Enables high performance, scalability, and ease of production deployment

For more information…

oracle.com/machine-learning

See also AskTOM OML Office Hours

Thank You

Mark Hornick
Oracle Machine Learning Product Management