Hadoop, Spark and R

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R and Data Mining Course

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Outline

Big Data [1]

- Volume: amount of data; from Terabytes to Petabytes
- Velocity: speed of data in and out; real time
- Variety: range of data types and sources; text, images, audio, video

[1] https://en.wikipedia.org/wiki/Big_data

Big Data [1]

- Volume: amount of data; from Terabytes to Petabytes
- Velocity: speed of data in and out; real time
- Variety: range of data types and sources; text, images, audio, video
- Variability: inconsistency of data
- Veracity: quality of data

[1] https://en.wikipedia.org/wiki/Big_data

Outline

Hadoop [2]

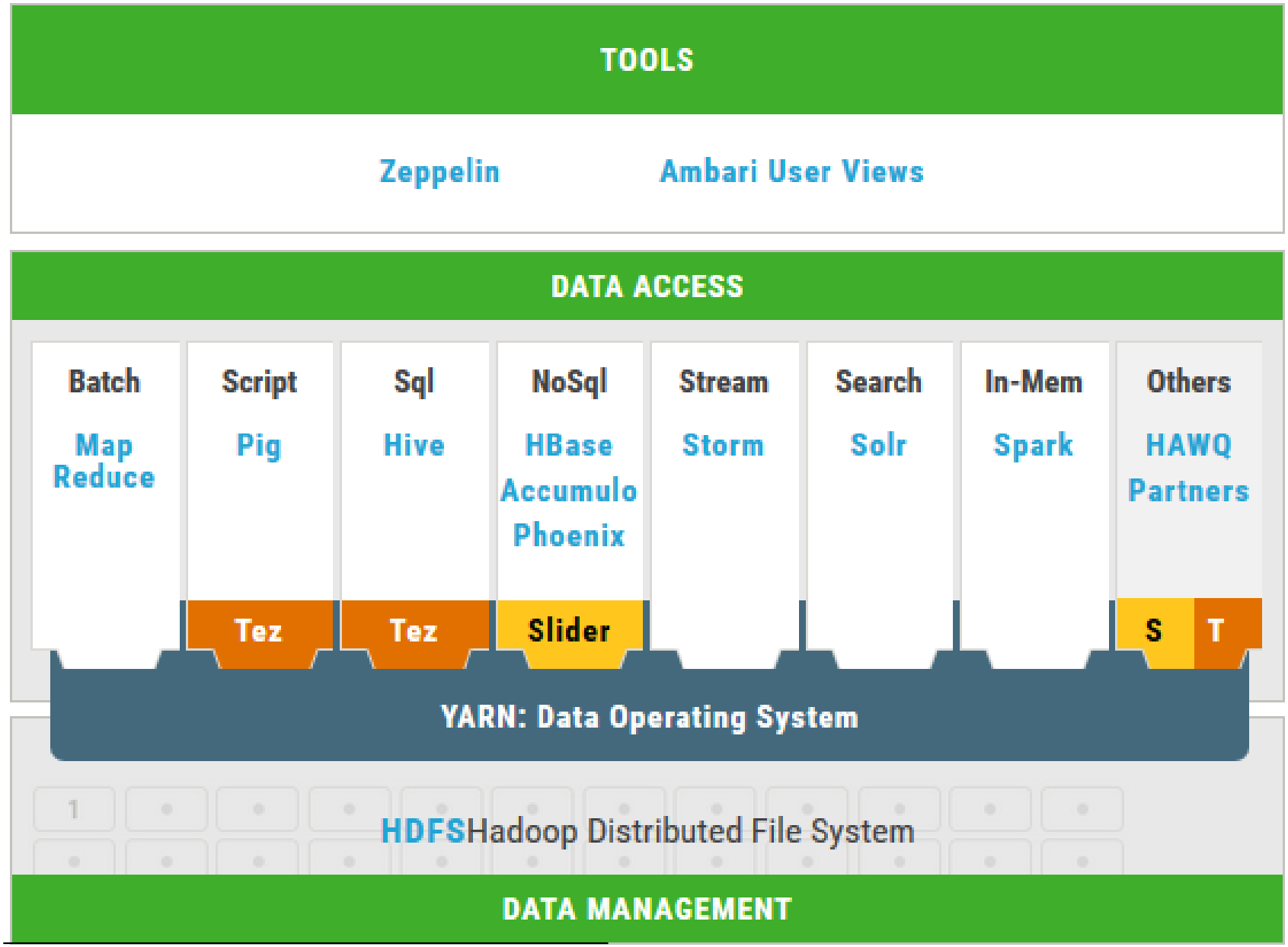
- Apache Hadoop is a framework for running applications on large cluster built of commodity hardware.
- Hadoop implements a computational paradigm named MapReduce, where the application is divided into many small fragments of work, each of which may be executed or re-executed on any node in the cluster.
- Distributed parallel computing
- Load ballancing
- Fault tolerant
- Scales to thousands of nodes

[2] `http://hadoop.apache.org/`

Hadoop

- HDFS: Hadoop Distributed File System
- YARN: a framework for job scheduling and cluster resource management
- MapReduce: a framework for parallel processing of large data sets

Hortonworks Data Platform (HDP) [3]



[3] http://hortonworks.com/products/data-center/hdp/

Tools/Applications on Hadoop


- Pig: a high-level data-flow language and execution framework for parallel computation
- Hive: a data warehouse infrastructure that provides data summarization and ad hoc querying
- HBase: the Hadoop database, a distributed, scalable, big data store
- Cassandra: a scalable multi-master database with no single points of failure
- Mahout: a scalable machine learning and data mining library

Tools/Applications on Hadoop (continued)

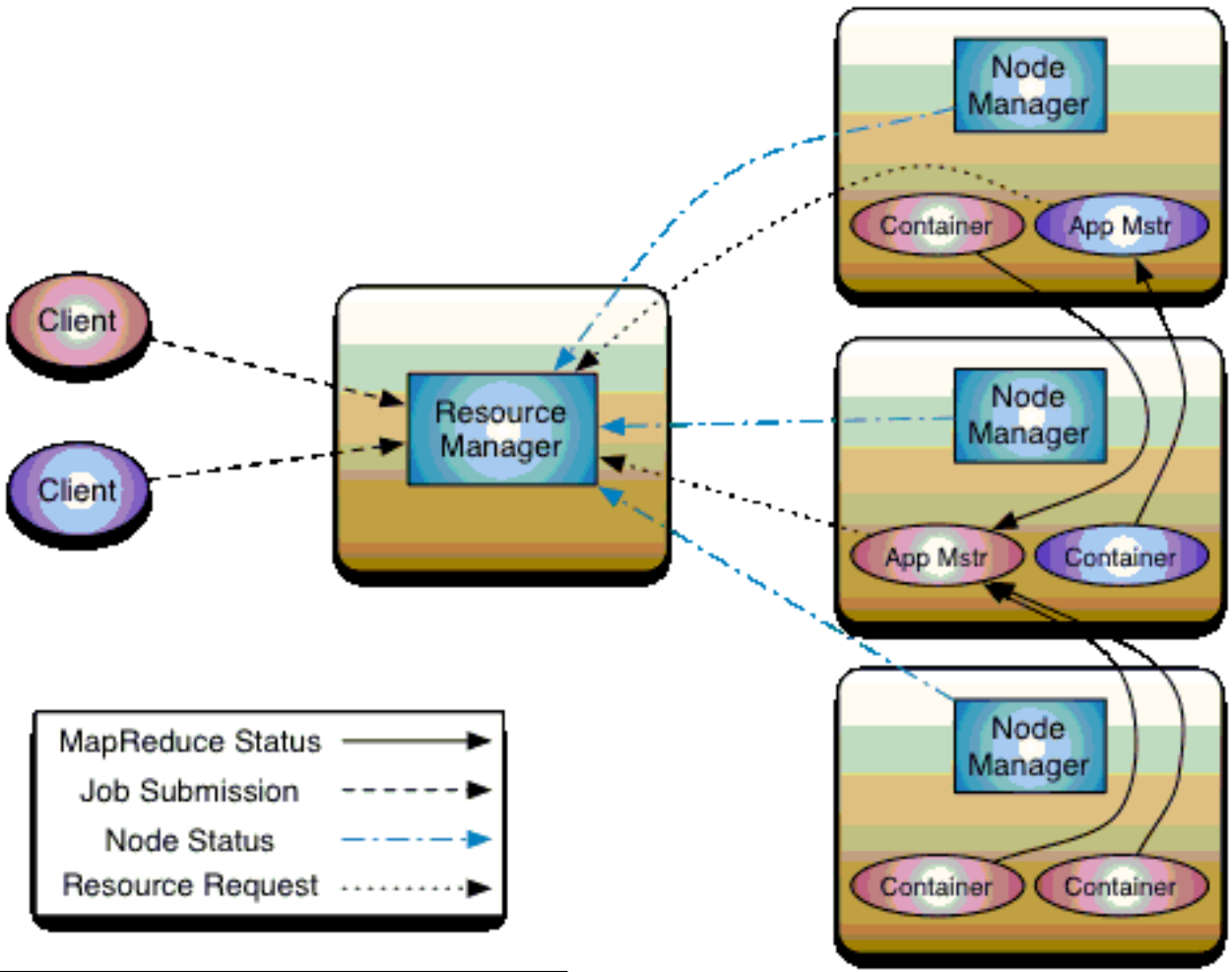
- Avro: a data serialization system
- Ambari: a web-based tool for provisioning, managing, and monitoring Apache Hadoop clusters
- Zeppelin: a web-based notebook that enables interactive data analytics, supporting many interpreters such as Apache Spark, Python, JDBC, Markdown and Shell
- Tez: a generalized data-flow programming framework, providing a powerful and flexible engine to execute an arbitrary DAG of tasks to process data for both batch and interactive use-cases
- Solr: a full-text search and indexing engine that enables large-scale search, navigation, and analytics on textual data
- Oozie: a tool for Hadoop users to automate commonly performed tasks

HDFS

- Hadoop Distributed File System
- The primary distributed storage used by Hadoop applications
- Stores very large files across machines in a large cluster
- NameNode: manages the file system metadata
- DataNodes: store the actual data
- A file is chopped into 128MB blocks.
- Each block is saved in 3 replicas on 3 different DataNodes.

YARN [4]

- resource management
- job scheduling and monitoring

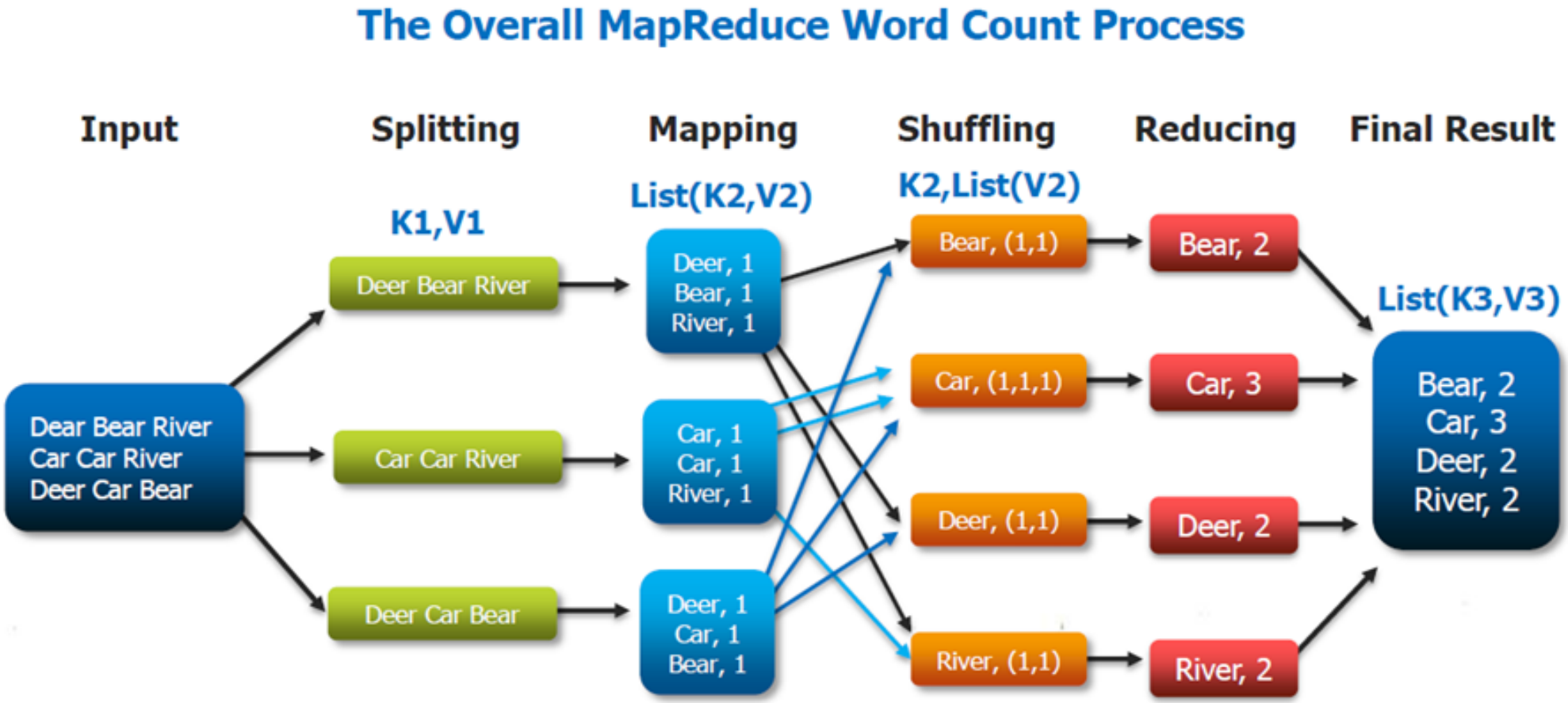


[4] http://hadoop.apache.org/docs/current/hadoop-yarn/hadoop-yarn-site/YARN.html

MapReduce [5]

- MapReduce expresses a large distributed computation as a sequence of distributed operations on data sets of key-value pairs.
- A MapReduce computation has two phases, a map phase and a reduce phase.
- Map: It splits the input data set into a large number of fragments and assigns each fragment to a map task. It also distributes the many map tasks across the cluster. For each input key-value pair (K1,V1), the map task invokes a map function that transmutes the input into a different key-value pair (K2,V2).
- Sort/shuffle: sorts the intermediate data set by key and produces a set of (K2, list(V2)) tuples so that all the values associated with a particular key appear together.
- Reduce: Each reduce task consumes the fragment of (K2, list(V2)) tuples assigned to it. For each such tuple it invokes a reduce function that transmutes the tuple into an output key-value pair (K3,V3).

An Example of MapReduce: Word Count [6]



[6] https://wikis.nyu.edu/display/NYUHPC/Big+Data+Tutorial+1%3A+MapReduce

An Example of MapReducing with R[7]

```
library(rmr2)
map <- function(k, lines) {
    words.list <- strsplit(lines, "\\s")
    words <- unlist(words.list)
    return(keyval(words, 1))
}
reduce <- function(word, counts) {
    keyval(word, sum(counts))
}
wordcount <- function(input, output = NULL) {
    mapreduce(input = input, output = output, input.format = "text",
        map = map, reduce = reduce)
}
## Submit job
out <- wordcount(in.file.path, out.file.path)
```

[7] From Jeffrey Breen's presentation on *Using R with Hadoop*
http://www.slideshare.net/RevolutionAnalytics/using-rwithhadoop

Mahout [8]

Apache Mahout is a suite of machine learning libraries designed to be scalable and robust. It provides 3 major features.

- A simple and extensible programming environment and framework for building scalable algorithms
- A wide variety of premade algorithms for Scala + Apache Spark, H2O, Apache Flink
- Samsara, a vector math experimentation environment with R-like syntax which works at scale

[8] https://mahout.apache.org/

Machine Learning Algorithms in Mahout

- Collaborative Filtering
- Classification
- Clustering
- Dimensionality Reduction
- Topic Models

Outline

Spark [9]

- a fast and general-purpose cluster computing system
- provides high-level APIs in Java, Scala, Python and R
- Spark SQL for SQL and structured data processing
- MLlib for large scale machine learning
- GraphX for graph processing
- Spark Streaming for processing real-time data streams

[9] http://spark.apache.org/

Spark Cluster

- Spark can run both by itself, or over existing cluster managers.
- Options for deployment:
  - Standalone Deploy Mode
  - Apache Mesos
  - Hadoop YARN

RDD

- RDD: Resilient Distributed Datasets, a fault-tolerant collection of elements that can be operated on in parallel.
- Two ways to create RDDs:
  - parallelizing an existing collection in your driver program
  - referencing a dataset in an external storage system
- RDDs support two types of operations:
  - transformations: create a new dataset from an existing one
  - actions: return a value to the driver program after running a computation on the dataset.
- All transformations are lazy, i.e., they do not actually perform any computations until an action is performed.

DataFrame

- A Spark DataFrame is a distributed collection of data organized into named columns.
- It is conceptually equivalent to a table in a relational database or a data frame in R.
- supports operations like selection, filtering, grouping, aggregation, etc.

DataFrame Operations: An Example[10]

```
# 1) select flights from JFK
# 2) group flights by destination
# 3) count the number of flights to each destination
dest_flights <- filter(df, df$origin == "JFK") %>%
                groupBy(df$dest) %>%
                summarize(count = n(df$dest))
```

%>%: pipe operation

[10] https://amplab.cs.berkeley.edu/publication/sparkr-scaling-r-programs-with-spark/

MLlib

- Spark's machine learning (ML) library
- ML Algorithms: common learning algorithms such as classification, regression, clustering, and collaborative filtering
- Featurization: feature extraction, transformation, dimensionality reduction, and selection
- Pipelines: tools for constructing, evaluating, and tuning ML Pipelines
- Persistence: saving and load algorithms, models, and Pipelines
- Utilities: linear algebra, statistics, data handling, etc.

MLlib Algorithms

- Classification: logistic regression, naive Bayes,...
- Regression: generalized linear regression, survival regression,...
- Decision trees, random forests, and gradient-boosted trees
- Recommendation: alternating least squares (ALS)
- Clustering: k-means, Gaussian mixtures (GMMs),...
- Topic modeling: Latent Dirichlet allocation (LDA)
- Frequent itemsets, association rules, and sequential pattern mining
- Model selection, cross validation
- ML workflow utilities

MLlib: an Example[11]

Building a generalized linear model

```
df <- createDataFrame(iris)
glm.model <- spark.glm(df, Sepal_Length ~ Sepal_Width + Species,
                       family="gaussian")
summary(glm.model)
pred <- predict(glm.model, df)
showDF(pred)
```

[11] https://spark.apache.org/docs/latest/sparkr.html

Outline

R and Big Data Platforms

- Hadoop
  - Hadoop (or YARN) - a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models
  - R Packages: *RHadoop*, *RHIPE*
- Spark
  - Spark - a fast and general engine for large-scale data processing, which can be 100 times faster than Hadoop
  - *SparkR* - R frontend for Spark
- H2O
  - H2O - an open source in-memory prediction engine for big data science
  - R Package: *h2o*
- MongoDB
  - MongoDB - an open-source document database
  - R packages: *rmongodb*, *RMongo*

R and Hadoop

- Packages: *RHadoop*, *RHive*
- RHadoop[12] is a collection of R packages:
  - *rhdfs* - connect to Hadoop Distributed File System (HDFS)
  - *rhbase* - connect to the NoSQL HBase database
  - *plyrmr* - perform common data manipulation operations on very large data sets stored on Hadoop
  - *rmr2* - perform data analysis with R via MapReduce on a Hadoop cluster
  - *ravro* - read and write avro files
- You can play with it on a single PC (in standalone or pseudo-distributed mode), and your code developed on that will be able to work on a cluster of PCs (in full-distributed mode)!
- A video showing Wordcount MapReduce in R
  `http://www.youtube.com/watch?v=hSrW0Iwghtw`

[12] `https://github.com/RevolutionAnalytics/RHadoop/wiki`

R and Spark

- SparkR
- sparklyr

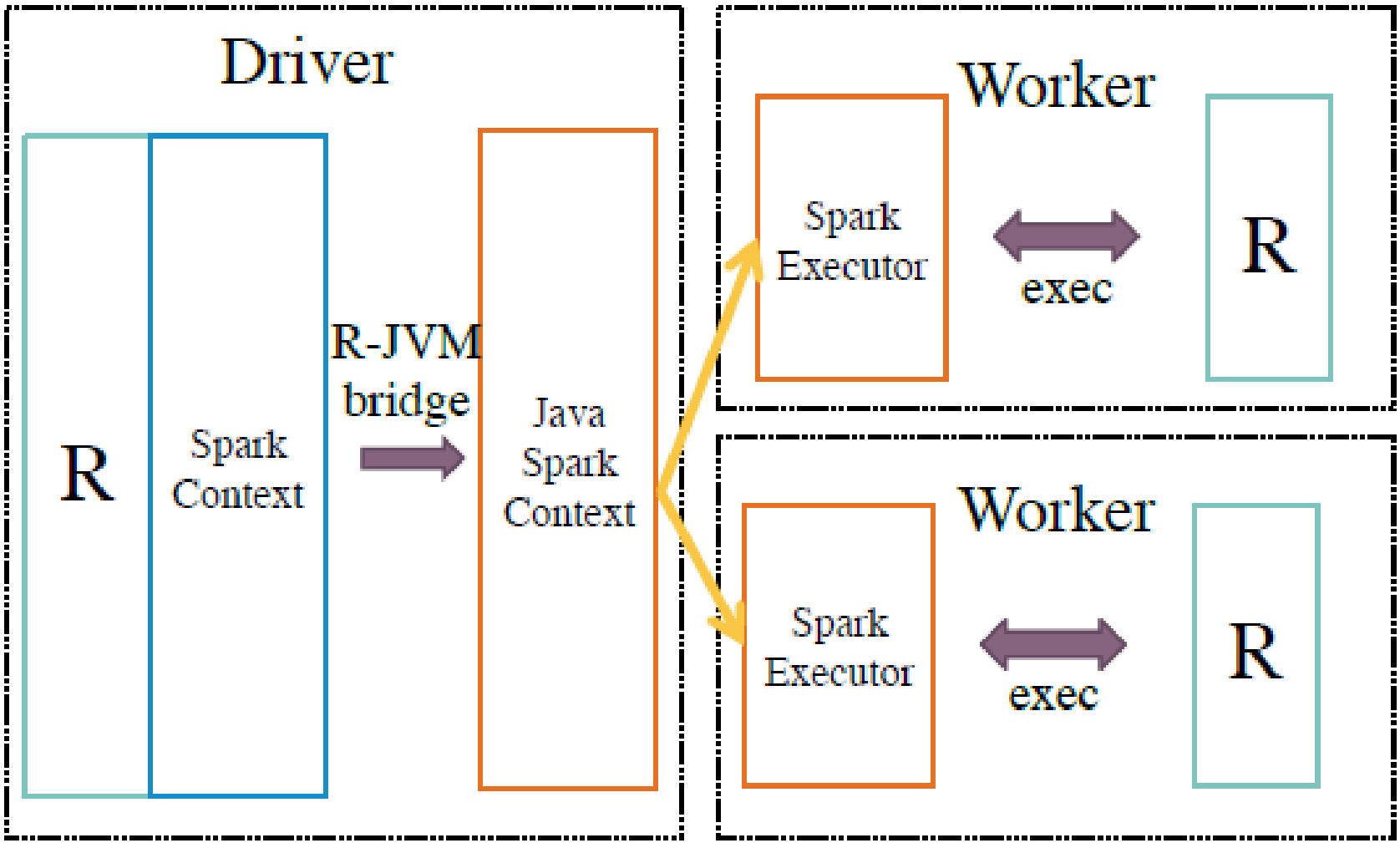
SparkR [14]

- SparkR: R on Spark
- an R package that provides a light-weight frontend to use Apache Spark from R
- initially developed at the AMPLab, UC Berkeley
- has been a part of the Apache Spark since v1.4 released in June 2015
- provides a distributed data frame implementation that supports operations like selection, filtering, aggregation etc. (similar to R data frames, dplyr) but on large datasets.
- supports distributed machine learning using MLlib.
- SparkR: Scaling R Programs with Spark. Shivaram Venkataraman et al., In Proc. of SIGMOD'16. [13]

[13] https://amplab.cs.berkeley.edu/publication/sparkr-scaling-r-programs-with-spark/

[14] https://spark.apache.org/docs/latest/sparkr.html

SparkR Architecture[15]



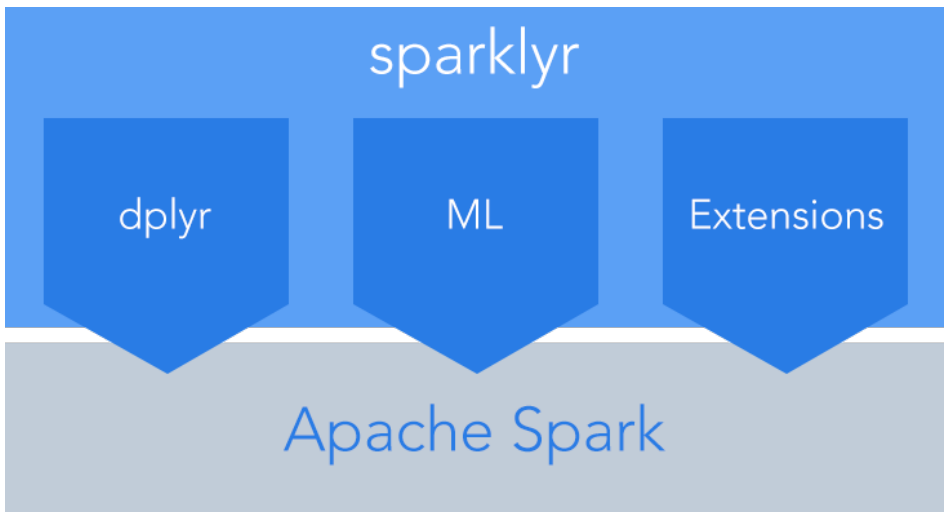
[15] https://amplab.cs.berkeley.edu/publication/sparkr-scaling-r-programs-with-spark/

Machine Learning Algorithms Supported by SparkR

- Generalized Linear Model
- Accelerated Failure Time (AFT)
- Survival Regression Model
- Naive Bayes Model
- K-means

sparklyr [16]

- sparklyr - an R interface for Apache Spark
- Provide a complete dplyr backend for data manipulation
- Filter and aggregate Spark datasets then bring them into R for analysis and visualization
- Distributed machine learning from R: using Spark MLlib or H2O Sparkling Water
- Create extensions that call the full Spark API and provide interfaces to Spark packages.



[16] http://spark.rstudio.com/

MLlib Algorithms

- `ml_kmeans`: K-means Clustering
- `ml_linear_regression`: Linear Regression
- `ml_logistic_regression`: Logistic Regression
- `ml_survival_regression`: Survival Regression
- `ml_generalized_linear_regression`: Generalized Linear Regression
- `ml_decision_tree`: Decision Trees
- `ml_random_forest`: Random Forests
- `ml_gradient_boosted_trees`: Gradient-Boosted Trees
- `ml_pca`: Principal Components Analysis
- `ml_naive_bayes`: Naive-Bayes
- `ml_multilayer_perceptron`: Multilayer Perceptron
- `ml_lda`: Latent Dirichlet Allocation
- `ml_one_vs_rest`: One vs Rest

H2O Machine Learning Algorithms

- `h2o.glm`: Generalized Linear Model
- `h2o.deeplearning`: Multilayer Perceptron
- `h2o.randomForest`: Random Forest
- `h2o.gbm`: Gradient Boosting Machine
- `h2o.naiveBayes`: Naive Bayes
- `h2o.prcomp`: Principal Components Analysis
- `h2o.svd`: Singular Value Decomposition
- `h2o.glrm`: Generalized Low Rank Model
- `h2o.kmeans`: K-Means Clustering
- `h2o.anomaly`: Anomaly Detection
- `h2o.ensemble, h2ostack`: Ensemble/stacking

Outline

Set up a Hadoop/Spark Cluster

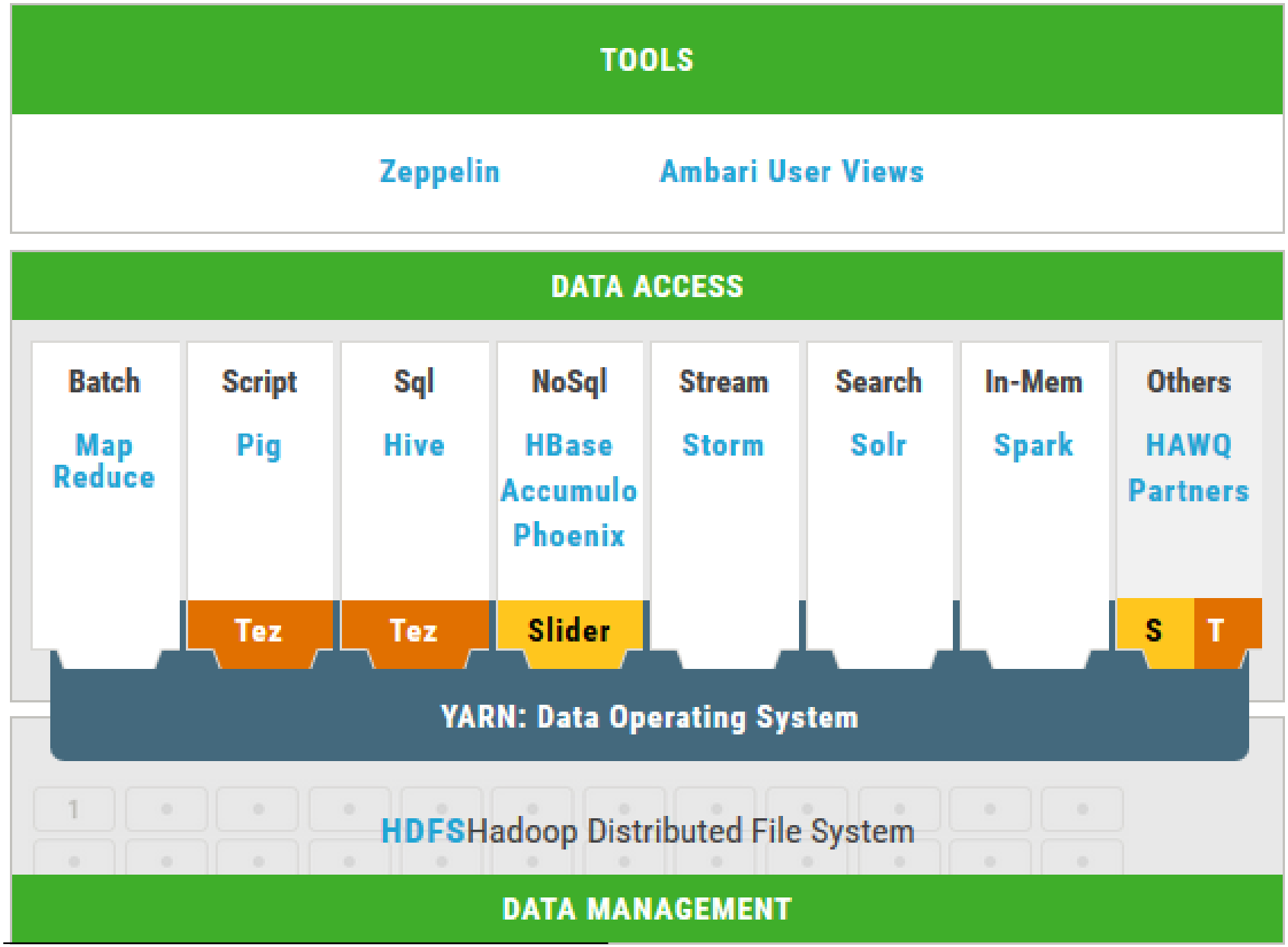
- On-premise cluster
  - Apache
  - Hortonworks
  - MapR
  - Cloudera:
    `http://www.cloudera.com/`
- Cloud solutions
  - Amazon Web Services (AWS):
    `https://aws.amazon.com/`
  - Microsoft Azure:
    `http://azure.microsoft.com`
  - Google Cloud Platform:
    `https://cloud.google.com/hadoop/`

Apache.org

Download Hadoop and Spark from Arache.org and install them

- Hadoop
  `http://hadoop.apache.org/releases.html`
- Spark
  `http://spark.apache.org/downloads.html`

Hortonworks Data Platform (HDP) [17]



[17] http://hortonworks.com/products/data-center/hdp/

Hortonworks Sandbox

- A personal, portable Apache Hadoop and its ecosystem environment
- On a virtual machine: Virtual Box, VMware, Docker
- On cloud: Microsoft Azure
- Good for learning Hadoop, Spark, Pig, Hive, etc.
- Download for free: `http://hortonworks.com/downloads/`

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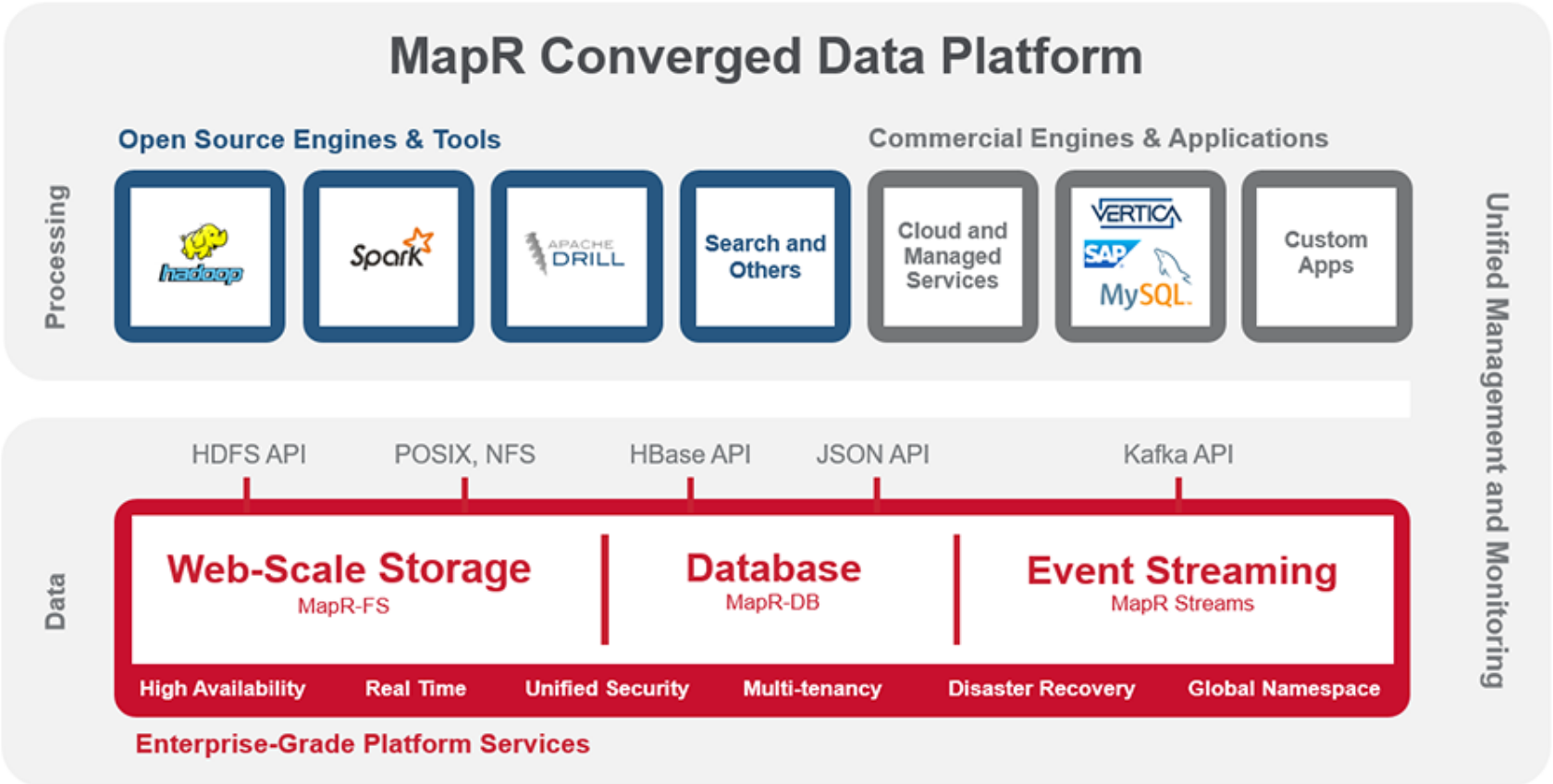
To set up a cluster, use Hortonworks Data Platform, not Sandbox.

MapR Converged Data Platform [18]



- It integrates Hadoop, Spark, and Apache Drill with real-time database capabilities, global event streaming, and scalable enterprise storage.
- Free community edition: `https://www.mapr.com/products/hadoop-download`

[18] `https://www.mapr.com/products/mapr-converged-data-platform`

MapR Converged Data Platform [19]

Open source engines and tools

[19] https://www.mapr.com/products/mapr-converged-data-platform

Outline

Online Resources

- Book *R and Data Mining: Examples and Case Studies*

  `http://www.rdatamining.com/docs/RDataMining-book.pdf`
- R Reference Card for Data Mining

  `http://www.rdatamining.com/docs/RDataMining-reference-card.pdf`
- Free online courses and documents

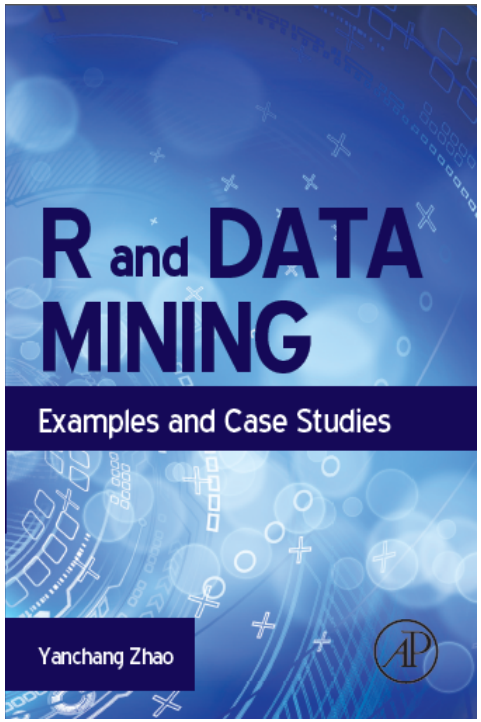
  `http://www.rdatamining.com/resources/`

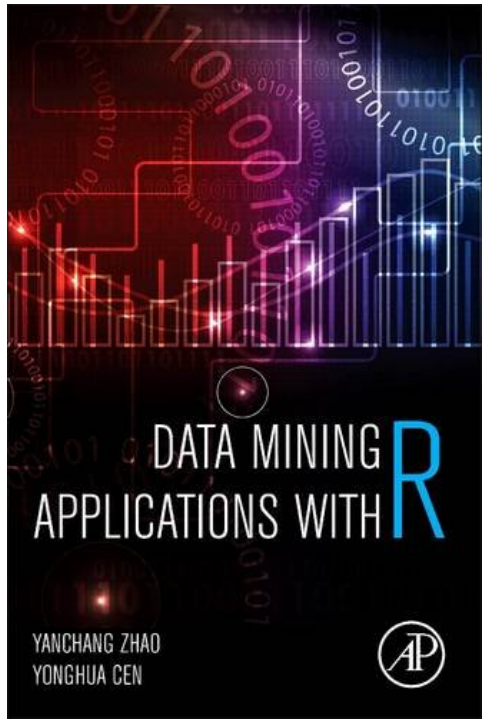
  `http://www.rdatamining.com/big-data/resources/`
- RDataMining Group on LinkedIn (26,000+ members)

  `http://group.rdatamining.com`
- Twitter (3,300+ followers)

  @RDataMining

The End





Thanks!

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