Data Science with Groovy

Presented by
Dr Paul King

Dr Paul King

OCI Groovy Lead

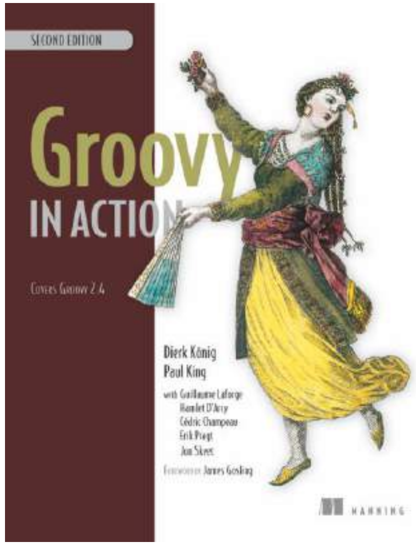
V.P. and PMC Chair Apache Groovy

Author: https://www.manning.com/books/groovy-in-action-second-edition

https://speakerdeck.com/paulk/groovy-data-science

https://github.com/paulk-asert/groovy-data-science

@paulk_asert



OBJECT COMPUTING

WE ARE SOFTWARE ENGINEERS.

We deliver mission-critical software solutions that accelerate innovation within your organization and stand up to the evolving demands of your business.

Grails

Groovy

MICRONAUT

WE ARE SOFTWARE ENGINEERS.

OBJECT COMPUTING

We deliver mission-critical software solutions that accelerate innovation within your organization and stand up to the evolving demands of your business.

AREAS OF EXPERTISE

INDUSTRIAL IoT

We equip industrial environments with seamless connectivity and real-time analytics that reduce operating costs and deliver on customer demands.

MACHINE LEARNING

We can modernize your legacy applications and enable scalable, integrated AI capabilities tailored to your unique sets of data.

BLOCKCHAIN CONSULTING

We are at the forefront of blockchain technology, and we have practical, real-world experience with its implementation.

CLOUD SOLUTIONS

We combine software engineering expertise with cloud-native architecture to accelerate innovation within your organization.

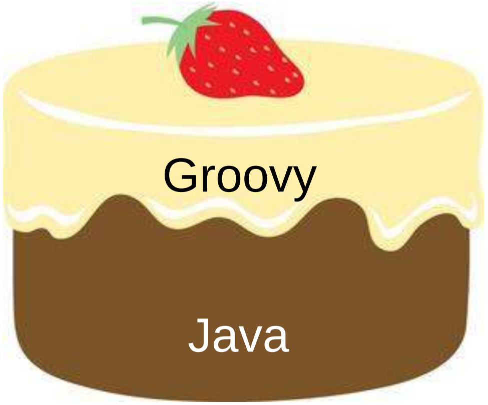
What is Groovy?

It's like a super version of Java:

- *Supports most Java syntax but allows simpler syntax for many constructs*
- *Supports all Java libraries but provides many extensions and its own productivity libraries*
- *Has both a static and dynamic nature*
- *Extensible language and tooling*

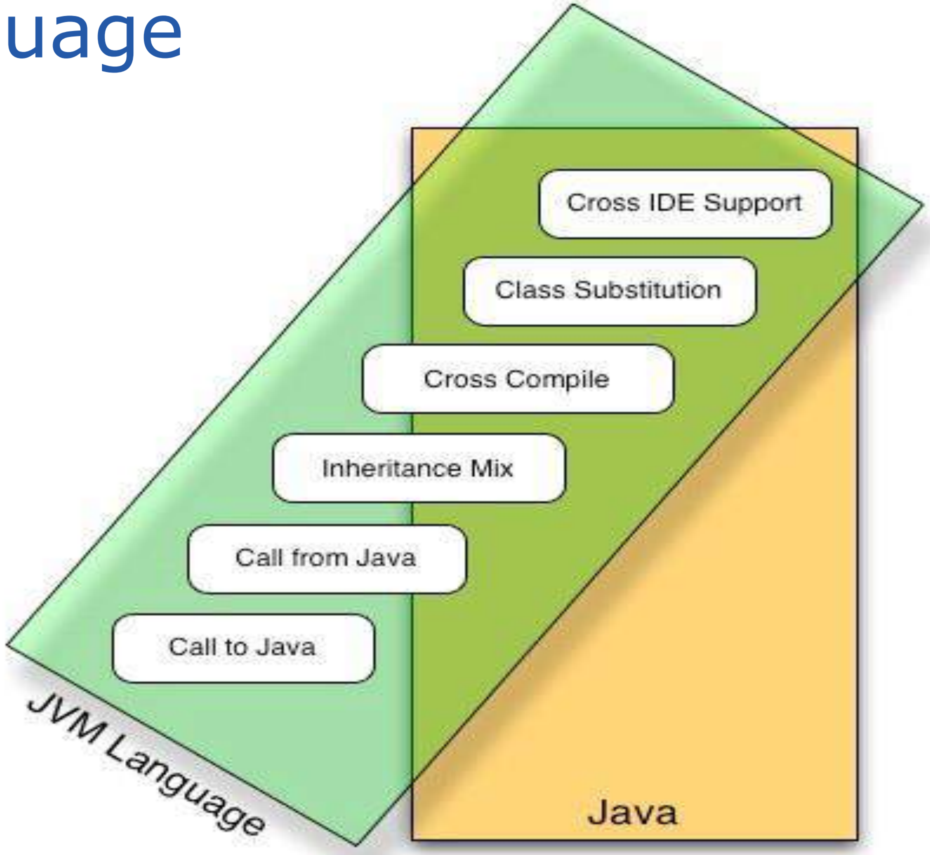
Groovy has a low learning curve, particularly for Java developers

Groovy is Java's friend



Seamless integration

- IDEs provide cross-language compile, navigation, and refactoring
- Arbitrarily mix source language
- Drop-in replace any class
- Overloaded methods
- Syntax alignment
- Shared data types



Java-like or concise shortcuts

```java
import java.util.List;
import java.util.ArrayList;

class Main {
    private List keepShorterThan(List strings, int length) {
        List result = new ArrayList();
        for (int i = 0; i < strings.size(); i++) {
            String s = (String) strings.get(i);
            if (s.length() < length) {
                result.add(s);
            }
        }
        return result;
    }
    public static void main(String[] args) {
        List names = new ArrayList();
        names.add("Ted"); names.add("Fred");
        names.add("Jed"); names.add("Ned");
        System.out.println(names);
        Main m = new Main();
        List shortNames = m.keepShorterThan(names, 4);
        System.out.println(shortNames.size());
        for (int i = 0; i < shortNames.size(); i++) {
            String s = (String) shortNames.get(i);
            System.out.println(s);
        }
    }
}
```

```groovy
names = ["Ted", "Fred", "Jed", "Ned"]
println names
shortNames = names.findAll{ it.size() < 4 }
println shortNames.size()
shortNames.each{ println it }
```

Concise syntax including DSL friendly

```
import java.util.List;
import java.util.ArrayList;

class Main {
    private List keepShorterThan(List strings, int length) {
        List result = new ArrayList();
        for (int i = 0; i < strings.size(); i++) {
            String s = (String) strings.get(i);
            if (s.length() < length) {
                result.add(s);
            }
        }
        return result;
    }
    public static void main(String[] args) {
        List names = new ArrayList();
        names.add("Ted"); names.add("Fred");
        names.add("Jed"); names.add("Ned");
        System.out.println(names);
        Main m = new Main();
        List shortNames = m.keepShorterThan(nam
        System.out.println(shortNames.size());
        for (int i = 0; i < shortNames.size(); i++) {
            String s = (String) shortNames.get(i);
            System.out.println(s);
        }
    }
}
```

```
names = ["Ted", "Fred", "Jed", "Ned"]
println names
shortNames = names.findAll{ it.size() < 4 }
println shortNames.size()
shortNames.each{ println it }
```

```
given the names "Ted", "Fred", "Jed" and "Ned"
display all the names
display the number of names having size less than 4
display the names having size less than 4
```

Metaprogramming

```java
public final class Person {
    private final String first;
    private final String last;

    public String getFirst() {
        return first;
    }

    public String getLast() {
        return last;
    }

    @Override
    public int hashCode() {
        final int prime = 31;
        int result = 1;
        result = prime * result + ((first == null)
            ? 0 : first.hashCode());
        result = prime * result + ((last == null)
            ? 0 : last.hashCode());
        return result;
    }

    public Person(String first, String last) {
        this.first = first;
        this.last = last;
    }
    // ...
```

Java

```java
    // ...
    @Override
    public boolean equals(Object obj) {
        if (this == obj)
            return true;
        if (obj == null)
            return false;
        if (getClass() != obj.getClass())
            return false;
        Person other = (Person) obj;
        if (first == null) {
            if (other.first != null)
                return false;
        } else if (!first.equals(other.first))
            return false;
        if (last == null) {
            if (other.last != null)
                return false;
        } else if (!last.equals(other.last))
            return false;
        return true;
    }

    @Override
    public String toString() {
        return "Person(first:" + first
            + ", last:" + last + ")";
    }
}
```

boilerplate

Groovy's metaprogramming capabilities allow complex design patterns to be encapsulated within simple constructs.

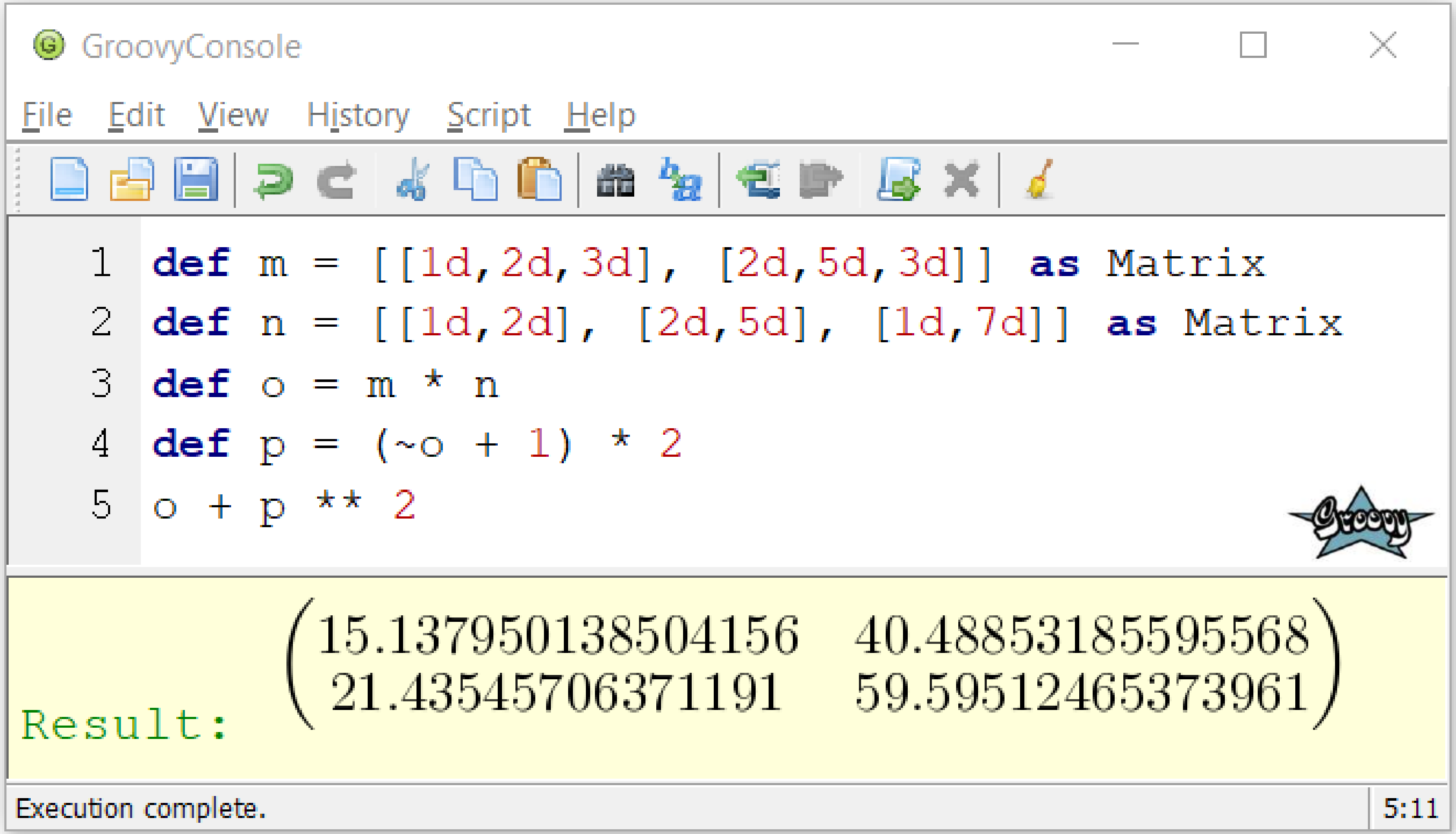
```groovy
@Immutable class Person {
    String first, last
}
```

Matrix manipulation example

```
import org.apache.commons.math3.linear.*;

public class MatrixMain {
    public static void main(String[] args) {
        double[][] matrixData = { {1d,2d,3d}, {2d,5d,3d}};
        RealMatrix m = MatrixUtils.createRealMatrix(matrixData);

        double[][] matrixData2 = { {1d,2d}, {2d,5d}, {1d, 7d}};
        RealMatrix n = new Array2DRowRealMatrix(matrixData2);

        RealMatrix o = m.multiply(n);

        // Invert p, using LU decomposition
        RealMatrix oInverse = new LUDecomposition(o).getSolver().getInverse();

        RealMatrix p = oInverse.scalarAdd(1d).scalarMultiply(2d);

        RealMatrix q = o.add(p.power(2));

        System.out.println(q);
    }
}
```

Array2DRowRealMatrix{{15.1379501385,40.488531856},{21.4354570637,59.5951246537}}

Operator overloading and extensible tools



groovyConsole

GroovyConsole

File Edit View History Script Help

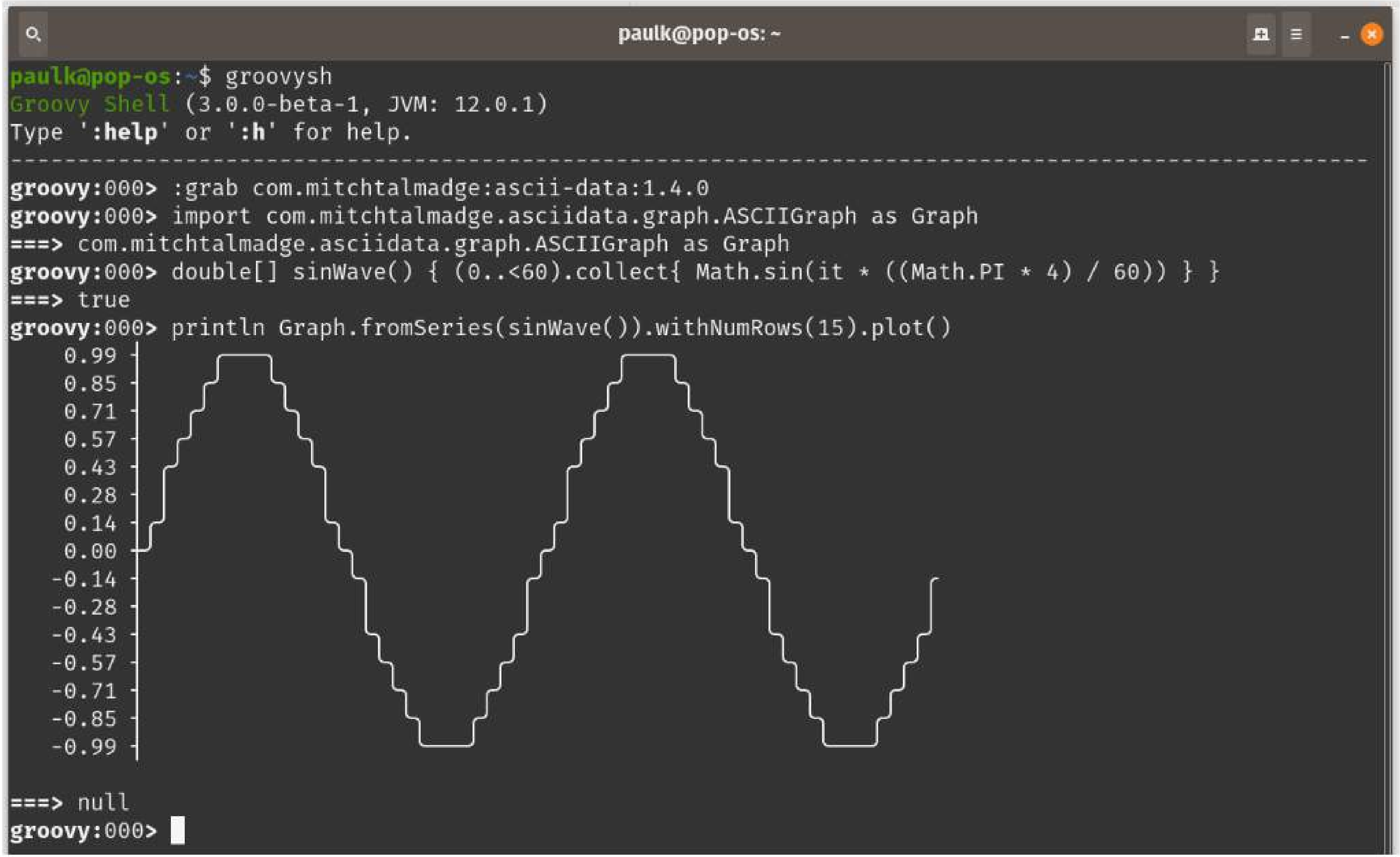
```groovy
@Grab('org.apache.opennlp:opennlp-tools:1.9.0')
import opennlp.tools.langdetect.*

u = 'http://apache.forsale.plus/opennlp/models/langdetect/1.8.3/langdetect-183.bin'
d = new LanguageDetectorME(new LanguageDetectorModel(new URL(u)))
a = 'Bienvenue à Paris'
b = 'Velkommen til København'

assert d.predictLanguage(a).lang == d.predictLanguage(b).lang
```

```
Exception thrown

Assertion failed:

assert d.predictLanguage(a).lang == d.predictLanguage(b).lang
       | |               |  |    |  | |               |  |
       | |               |  'fra'|  | |               |  'dan'
       | |               |       |  | |               'Velkommen til København'
       | |               |       |  | dan (0.024727160814654276)
       | |               |       |  opennlp.tools.langdetect.LanguageDetectorME@232a5780
       | |               |       false
       | |               'Bienvenue à Paris'
       | fra (0.018630393459062138)
       opennlp.tools.langdetect.LanguageDetectorME@232a5780


	at ConsoleScript12.run(ConsoleScript12:9)
```

Execution terminated with exception. 9:62

showing @Grab, power asserts and natural language processing

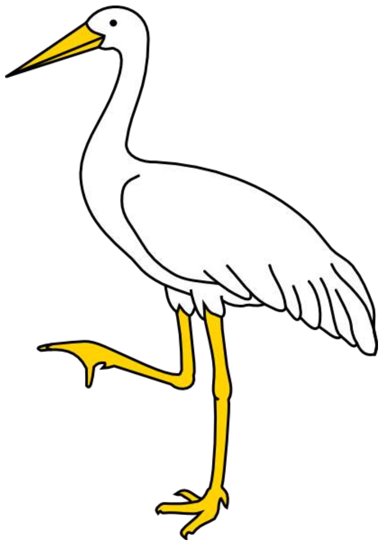
REPL for Groovy (groovysh)



The groovysh REPL is where you can program interactively.

Command chains and extensible type system

```
cranes have 2 legs
tortoises have 4 legs

there are 7 animals
there are 20 legs

display solution
```

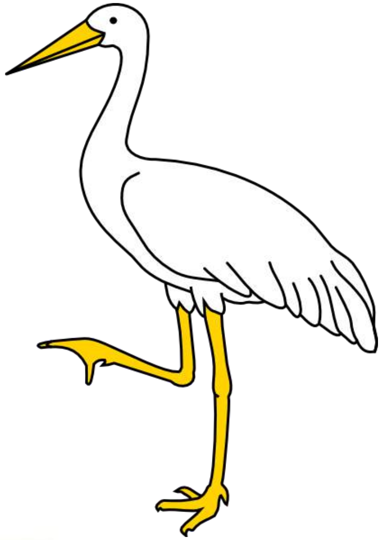


Cranes 4
Tortoises 3

Text file? No it’s a statically typed Groovy program which won’t compile if the animal names aren’t valid.
A constraint programming solver is used to find the solution.

Command chains and extensible type system

```
cranes have 2 legs
tortoises have 4 legs
millipedes have 1000 legs
there are 8 animals
there are 1020 legs

display solution
```



Cranes 4
Tortoises 3
Millipedes 1

Groovy frameworks plus entire Java ecosystem

GRAILS

Gradle

GRIFFON

GPars

Ratpack

GEB

CODENARC
Less Bugs Better Code

jupyter

BeakerX

SDKMAN!

MICRONAUT

Jenkins

spock
FRAMEWORK

Rich ecosystem.

Groovy frameworks plus entire Java ecosystem

```
class MathSpec extends Specification {
    def "maximum of two numbers"() {
      expect:
        Math.max(a, b) == c

      where:
        a | b || c
        1 | 3 || 3
        7 | 4 || 7
        0 | 0 || 0
    }
}
```

Rich ecosystem.

Groovy frameworks plus entire Java ecosystem

```
plugins {
    id 'groovy'
}

repositories {
    jcenter()
}

dependencies {
    implementation 'org.codehaus.groovy:groovy-all:2.5.7'

    testImplementation 'org.spockframework:spock-core:1.2-groovy-2.5'
}
```

Rich ecosystem.

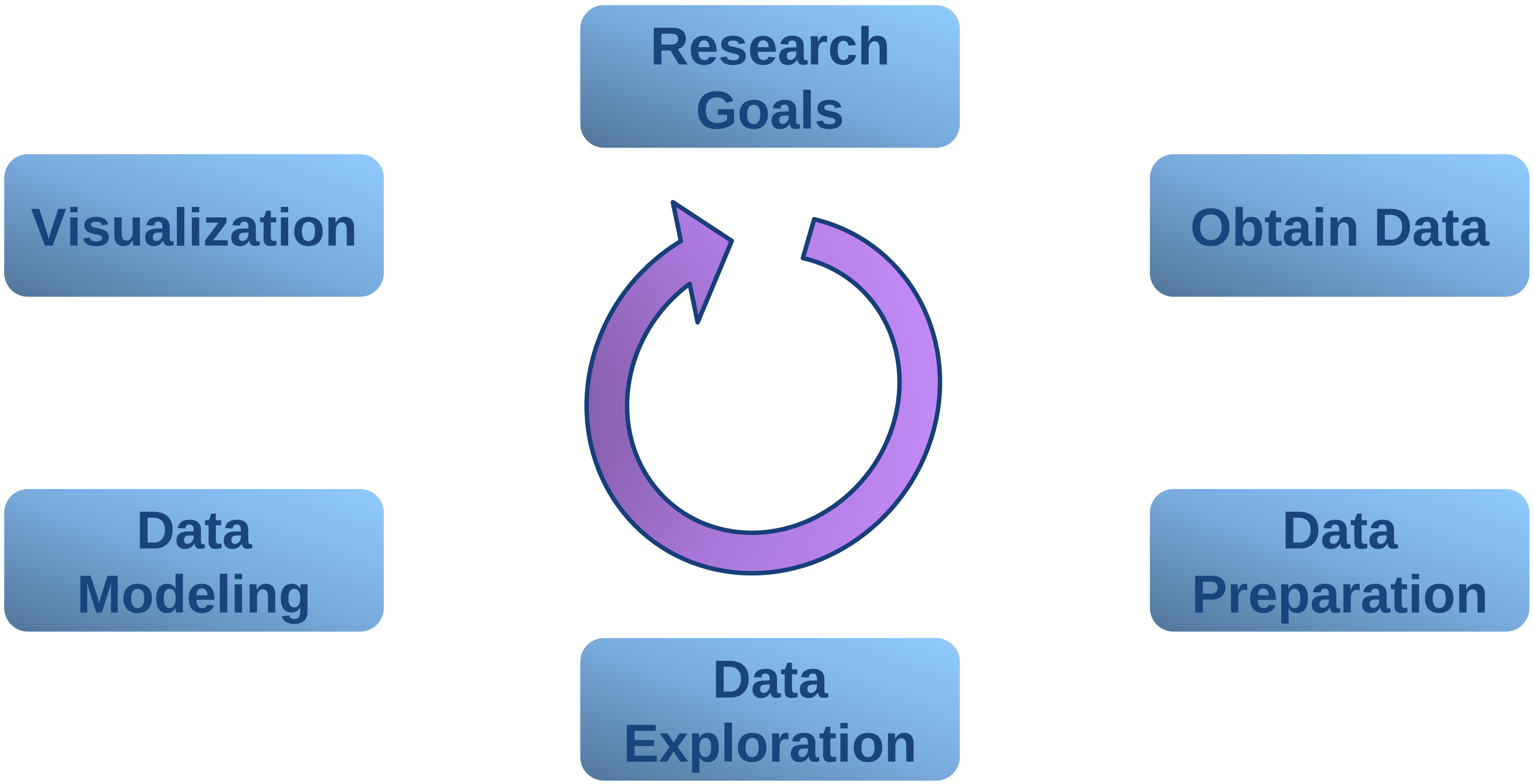
Groovy frameworks plus entire Java ecosystem

Data Parallelism: Fork/Join Map/Reduce	*Fixed coordination (for collections)*
Actors	*Explicit coordination*
Safe Agents	*Delegated coordination*
Dataflow	*Implicit coordination*

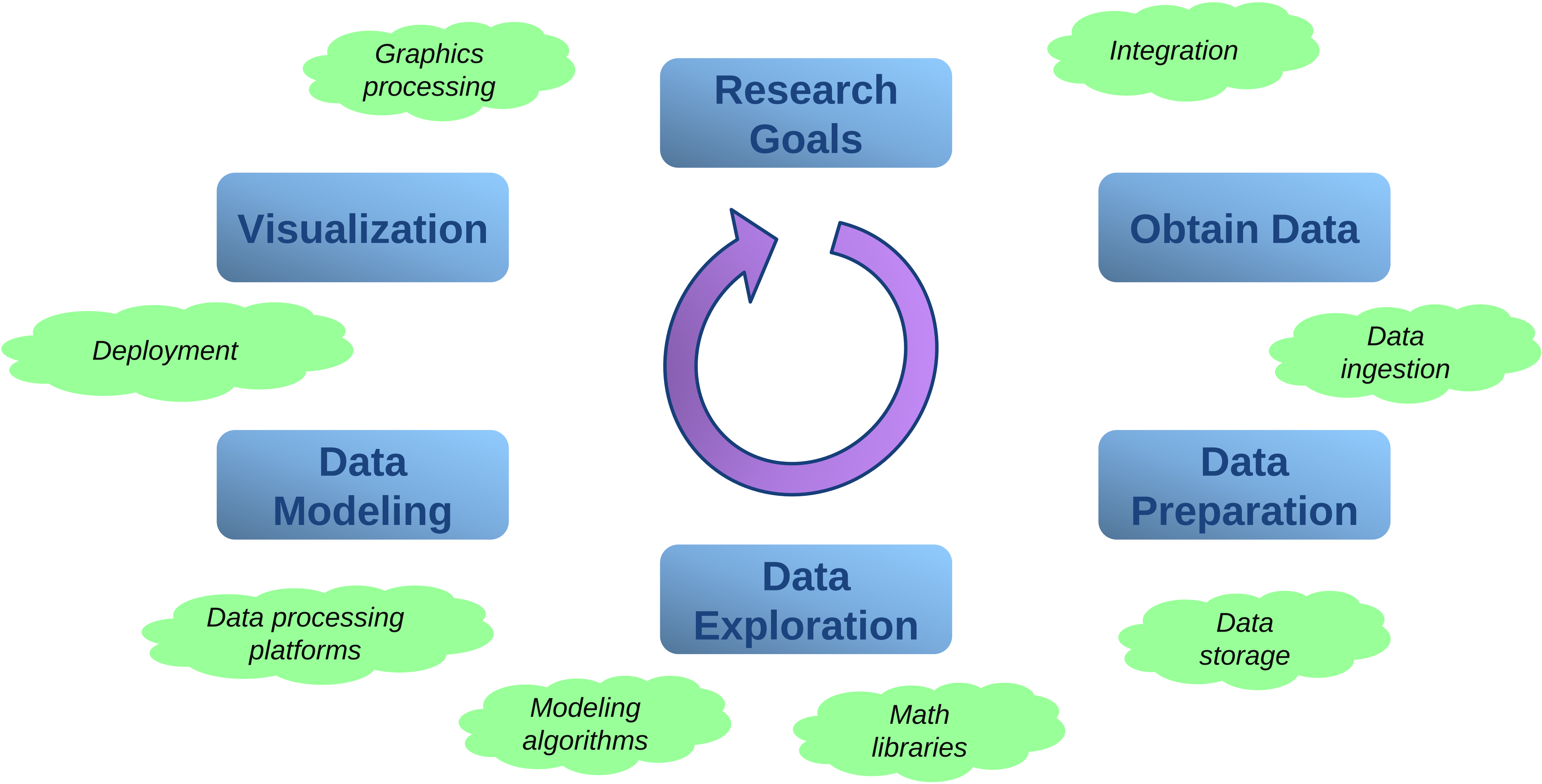
Rich ecosystem.

Source: ReGinA – Groovy in Action, Manning, 2nd edition

Data Science Process



Data Science Process



Libraries/Tools/Frameworks for Data Science - R

	Library	COMMITS	CONTRIBUTORS	FEATURES
DATA MANIPULATION	dplyr	4 354	136	· powerful library for data wrangling · works with local data frames and remote database tables · precise and simple command syntax
	data.table	3 211	43	· quick aggregation of large data · laconic flexible syntax and a wide suite of useful functions · friendly file reader and parallel file writer
	lubridate	1 427	45	· a set of functions to work with date and time format · easy and fast parsing of date-time data · expanded mathematical operations on time data
	jsonlite	908	11	· robust and quick parsing JSON objects in R · great tool for interacting with web APIs and building pipelines · functions to stream, validate, and prettify JSON data
GRAPHIC DISPLAYS	ggplot2	3 903	133	· powerful implementation of the grammar of graphics visualization · developed static graphics system · takes care of plot specifications
	Corrplot	299	8	· abilities to visualize correlation matrices and confidence intervals · contains algorithms to do matrix reordering · flexible appearance details settings
	lattice	132	0	· high-level visualization system · emphasis on multivariate data · efficiently copes with nonstandard requirements
HTML WIDGETS	plotly	2 989	26	· rich features and plenty of available charts · web-based toolbox for building visualizations · abilities to make ggplot2 graphics interactive
	ggvis	2 159	21	· implementation of an interactive grammar of graphic · incorporates shiny reactive programming model and dplyr grammar of data transformation
	DT DataTables	1 919	21	· displays R matrices and data frames as interactive HTML tables · creates sortable tables with a minimum of code · many useful features and styling options for tables
	rCharts	638	11	· interactive JS charts from R · tools for creation, customization, and sharing

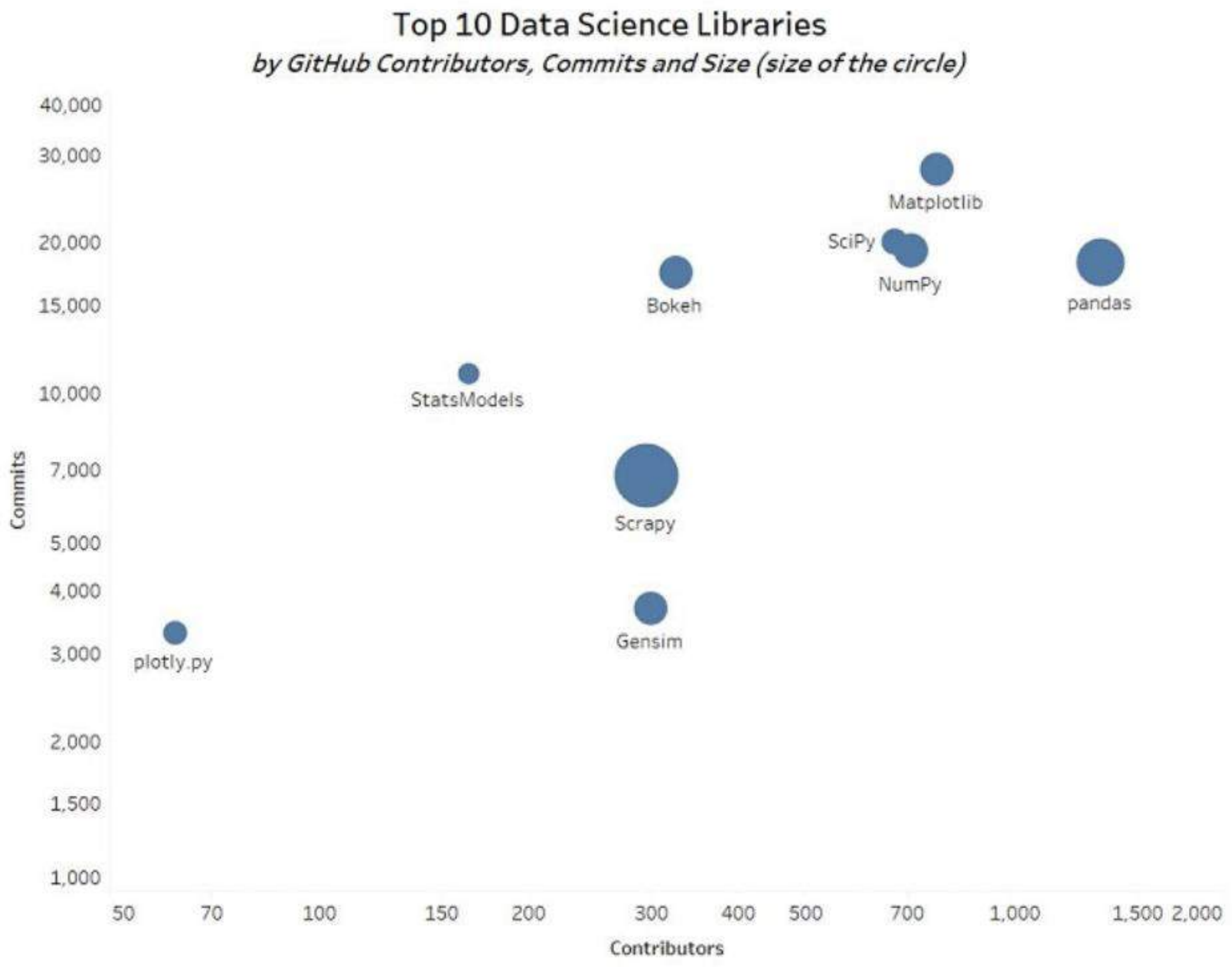
	Library	COMMITS	CONTRIBUTORS	FEATURES
REPRODUCIBLE RESEARCH	knitr	5 467	96	· transparent tool for easy dynamic report generation in R · enables integration of R code into LaTeX, LyX, HTML, Markdown, AsciiDoc, and reStructuredText documents
	rmarkdown	2 297	56	· next generation implementation of R Markdown based on pandoc · many static and dynamic output formats · abilities to define new formats for custom publishing requirements
	Slidify	302	7	· generates reproducible html5 slides from r markdown · allows embedded code chunks and mathematical formulas · rich sharing and customizing opportunities
MACHINE LEARNING	mlr	3 915	55	· extensible framework for classification, regression, survival analysis, and clustering · easy extension mechanism through S3 inheritance
	dmlc XGBoost	3 188	259	· implementation of the Gradient Boosted Decision Trees algorithm · reach tools for regression, classification, and ranking problems · high speed and performance
	caret	1 659	59	· many models for classification and regression · powerful tools and algorithms for creating predictive models
	gbm	731	26	· represents Generalized Boosted Regression Models · includes plenty of regression methods · tools variable selection and final stage precision modeling
	Prophet	190	20	· high-quality forecasts for time series data · manages data that has multiple seasonality with linear or non-linear growth · robust to missing data, shifts in the trend, and large outliers
	randomForest	56	0	· implements Breiman's random forest algorithm for classification and regression · builds multiple decision trees and gives back the mean prediction of the individual trees

Updated: December 2017

Created by ActiveWizards

Source: https://www.kdnuggets.com/2018/05/top-20-r-libraries-data-science-2018.html

Libraries/Tools/Frameworks for Data Science - Python



Source: https://www.kdnuggets.com/2018/11/top-python-data-science-libraries.html

Obtain data

Identify sources

- Internal/External (data providers)
- Databases, files, events, IoT
- Unstructured/structured
- Text, XML, JSON, YAML, CSV/spreadsheets, audio, images, video, web services
- Apache Tika
- JExcel
- Apache POI

Clarify ownership

Check quality

```
def jsonSlurper = new JsonSlurper()
def object = jsonSlurper.parseText('{ "myList": [4, 8, 15, 16, 23, 42] }')
assert object instanceof Map
assert object.myList instanceof List
assert object.myList == [4, 8, 15, 16, 23, 42]
```

```
def response = new XmlSlurper().parseText(books)
def authorResult = response.value.books.book[0].author
assert authorResult.text() == 'Miguel de Cervantes'
```

```
def qry = 'SELECT * FROM Author'
assert sql.rows(qry, 1, 3)*.firstname == ['Dierk', 'Paul', 'Guillaume']
assert sql.rows(qry, 4, 3)*.firstname == ['Hamlet', 'Cedric', 'Erik']
assert sql.rows(qry, 7, 3)*.firstname == ['Jon']
```

Data preparation

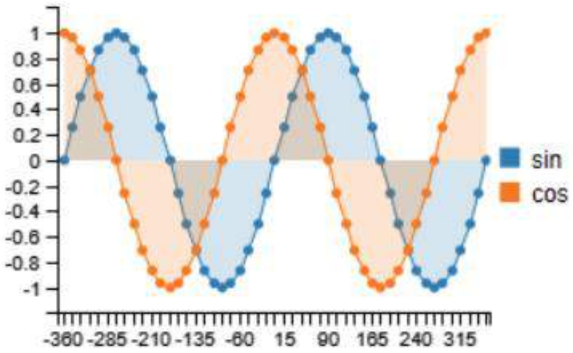
Collections:

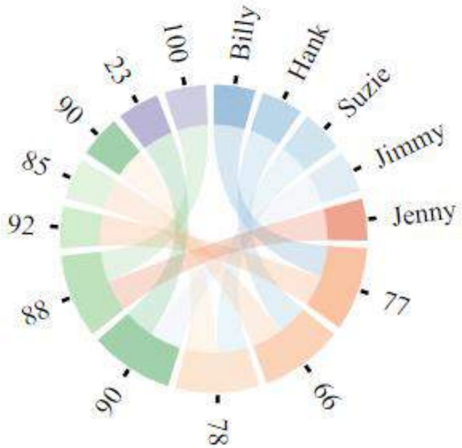
- Java: lists, maps, sets
- Groovy: literal notation, GDK methods, GPath
- Libraries
  - Google Guava https://github.com/google/guava
  - Apache Common Collections https://commons.apache.org/collections/

DataFrames:

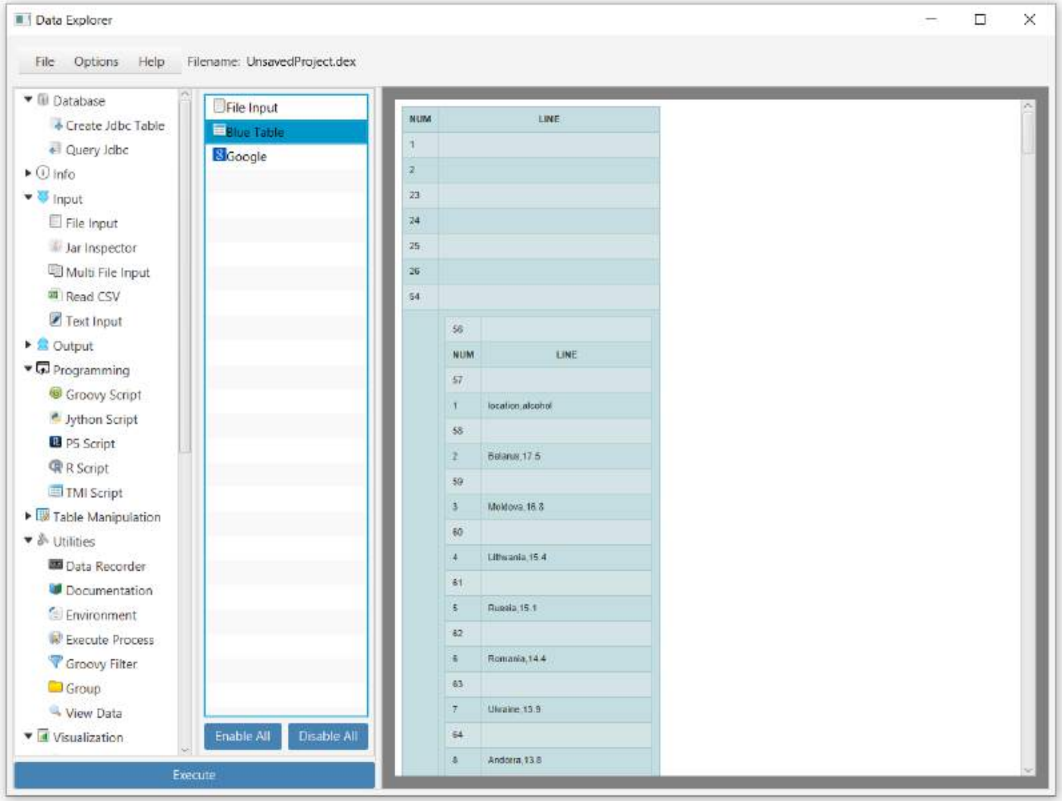
- Joinery https://cardillo.github.io/joinery/
  A data frame implementation in the spirit of Pandas or R data frames with show/plot
- Tablesaw https://jtablesaw.github.io/tablesaw/
  Java dataframe and visualization library
- Apache Spark DataFrames https://spark.apache.org/docs/latest/sql-programming-guide.html
  Equivalent to a table in a relational database or a data frame in R/Python
- Paleo https://github.com/netzwerg/paleo
  Immutable Java 8 data frames with typed columns (including primitives)

Data exploration - DEX





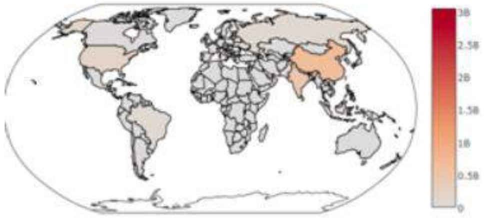
DEX : The Data Explorer

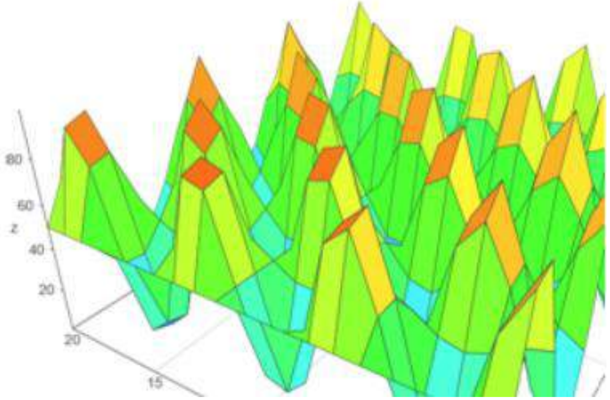


Dex

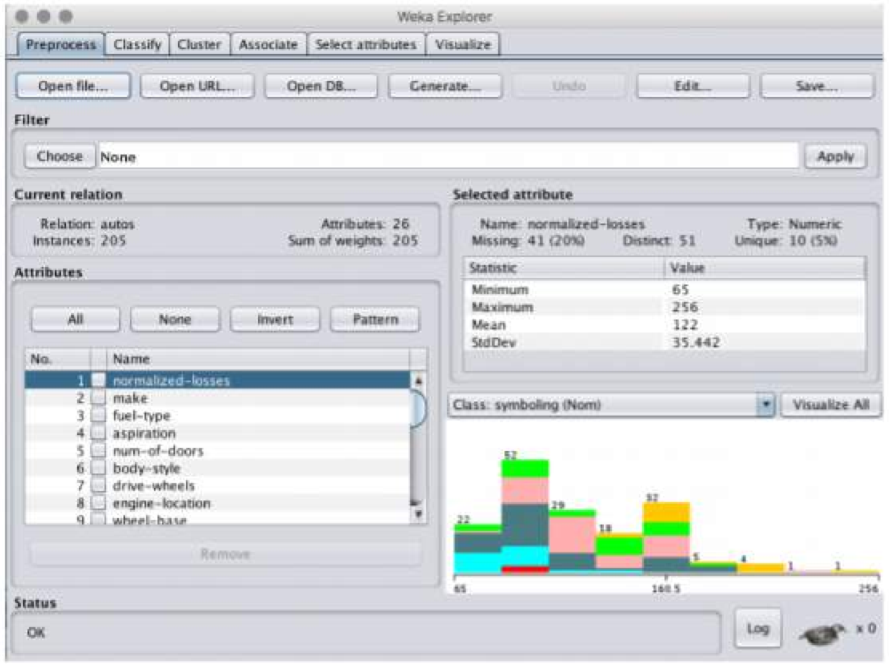
Dex : The data explorer is a powerful tool for data science. It is written in Groovy and Java on top of JavaFX and offers the ability to:

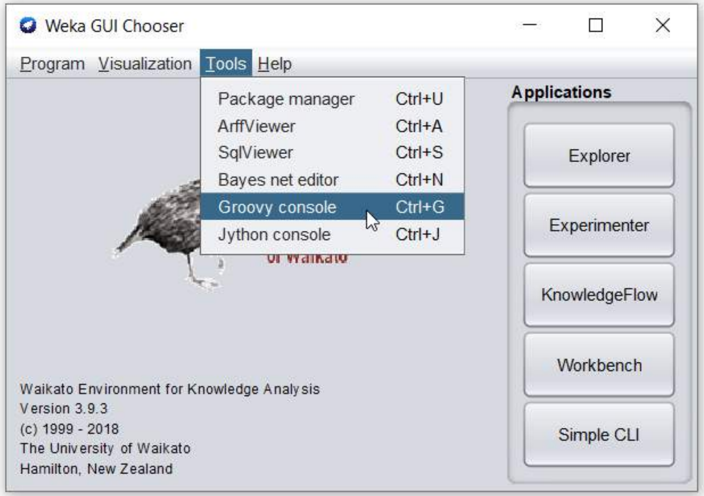
- Read in data from a variety of sources such files, programs and a variety of databases.
- Transform the data in a powerful ways.
- Apply powerful machine learning to the data via SMILE and R integration.
- Visualize the data in over 50 distinct ways.
- Output the data to a variety of databases and file formats.
- Extend Dex from within via templates and internal scripting. Save the extensions to reuse later.

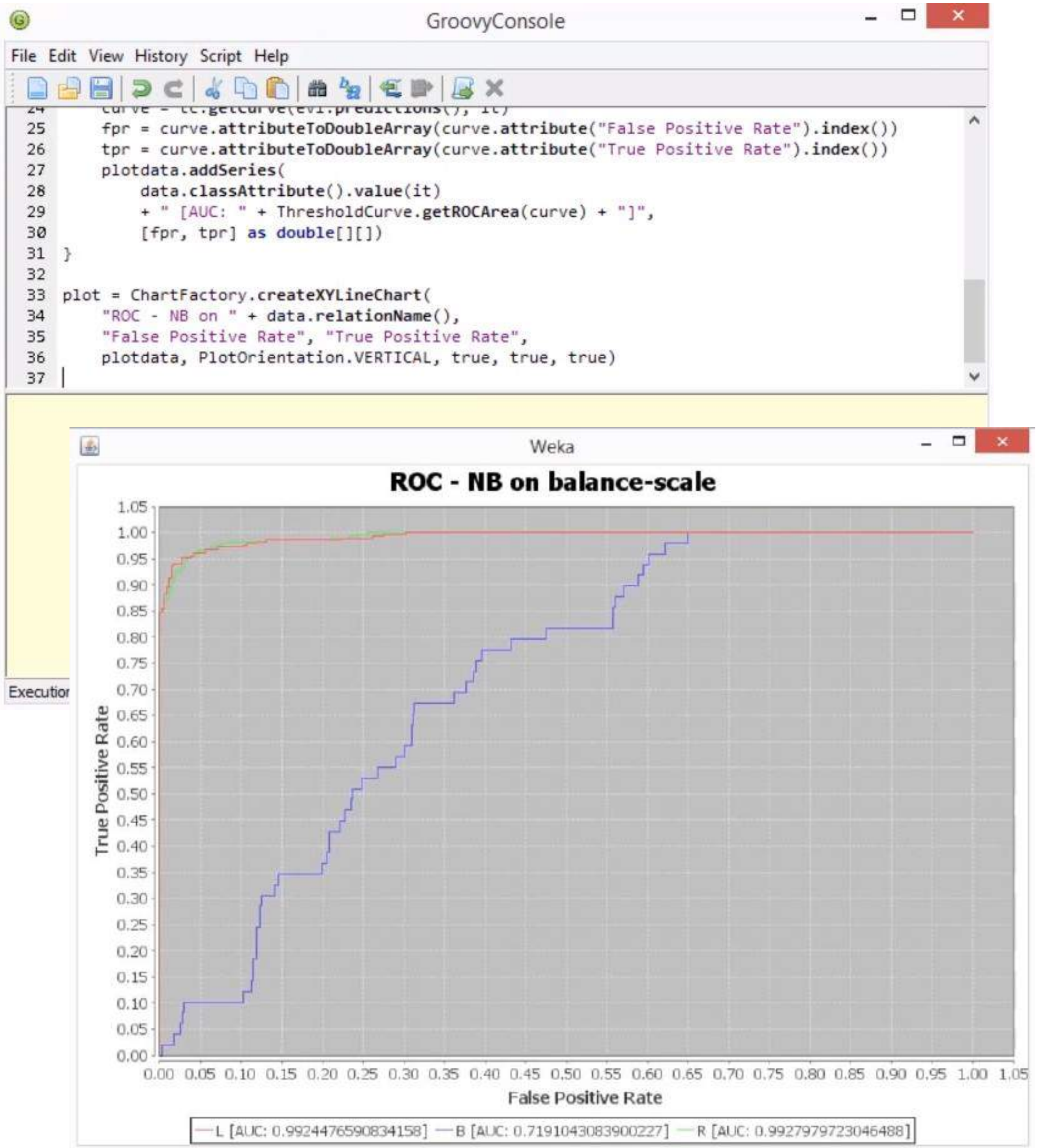




Data exploration - Weka



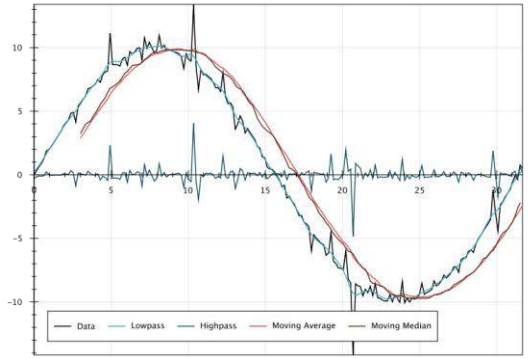


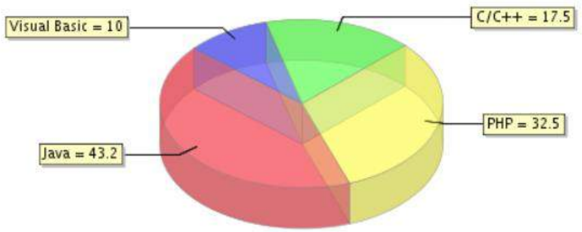


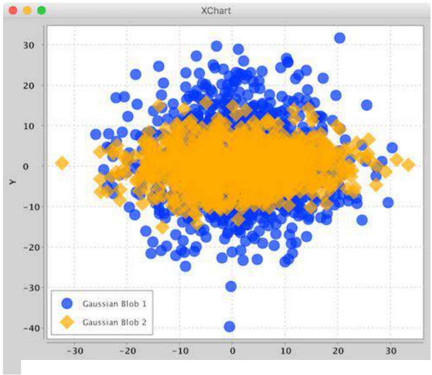
More info: https://www.youtube.com/watch?v=7quZv6WCTQc

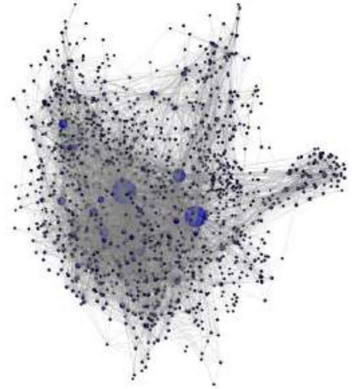
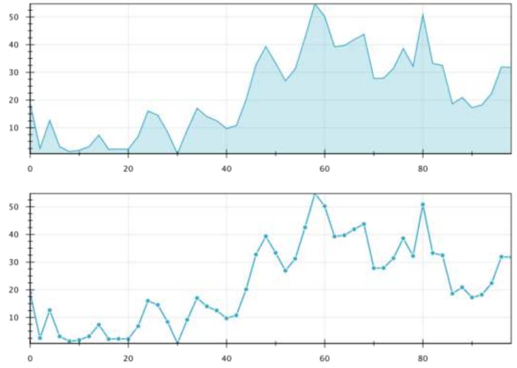
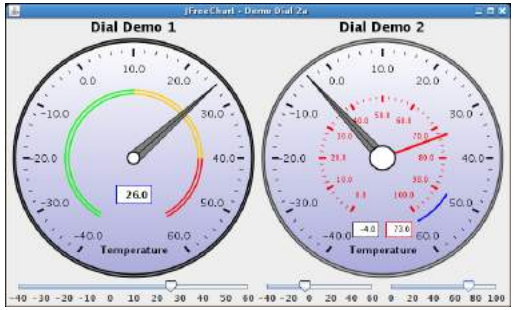
Visualization

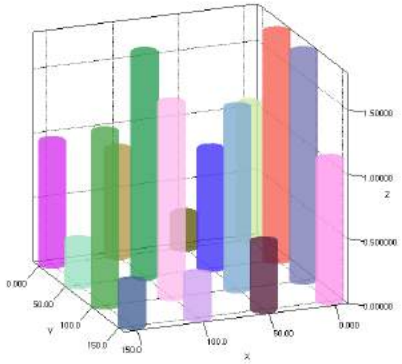
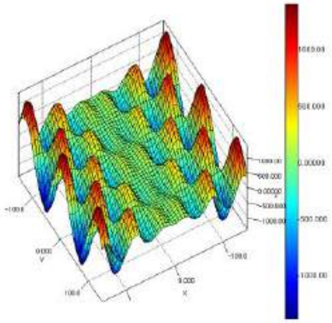
- Open-Source plotting libraries:
  GRAL, JFreeChart, Xchart, JMathPlot, Jzy3d, JavaFX, GroovyFX
- Types: Scatter plot, Line plot, Area plot, Pie plot, Donut plot, Horizontal bars, Vertical bars, Bubble plot, Radar plot, Box plot, Raster plot, Contour plot, Gauge plot, Step plot, Gantt plot, Histogram
- Features: Multiple axes, Logarithmic axes, Line smoothing, Data filtering/aggregation





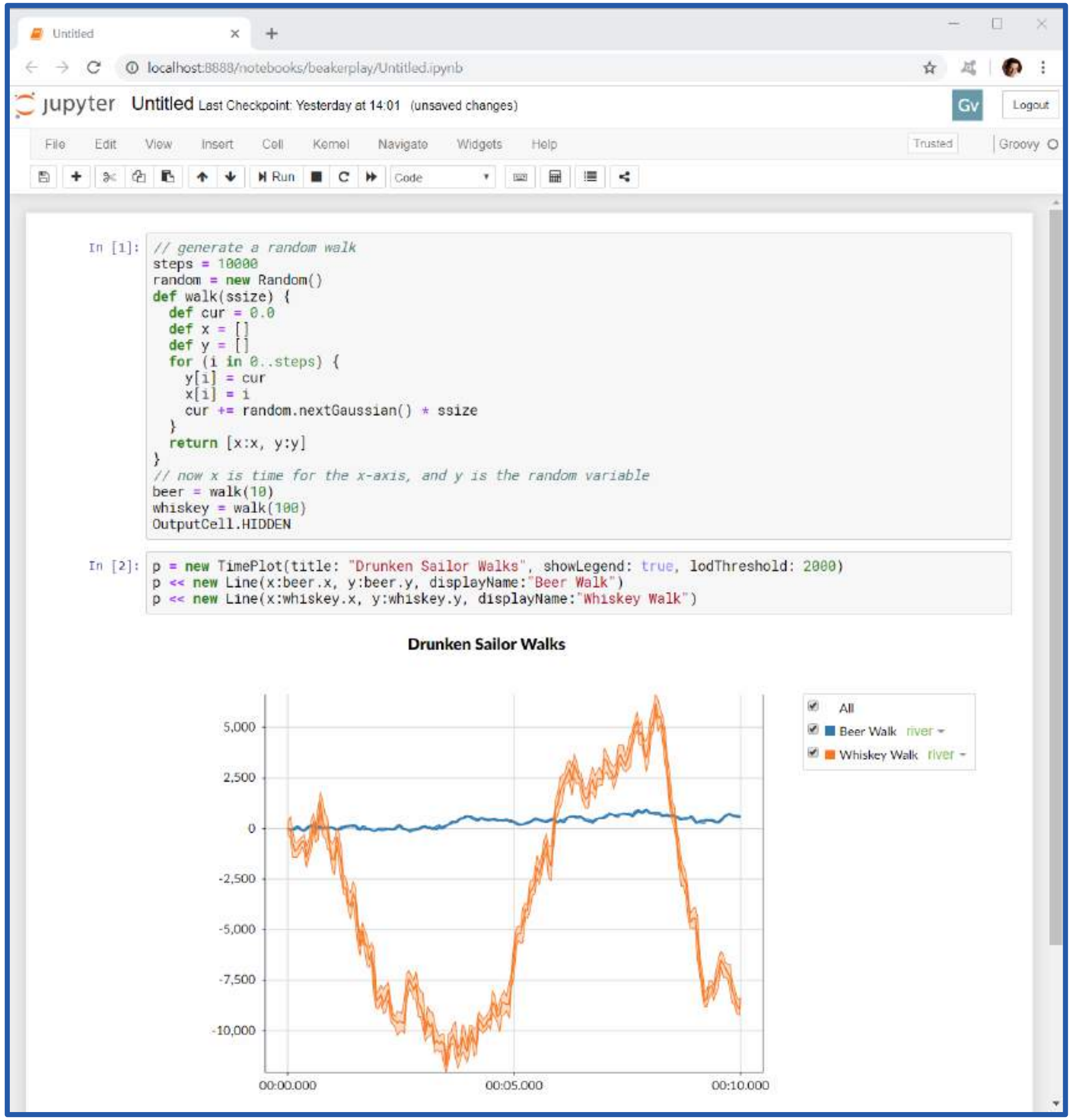


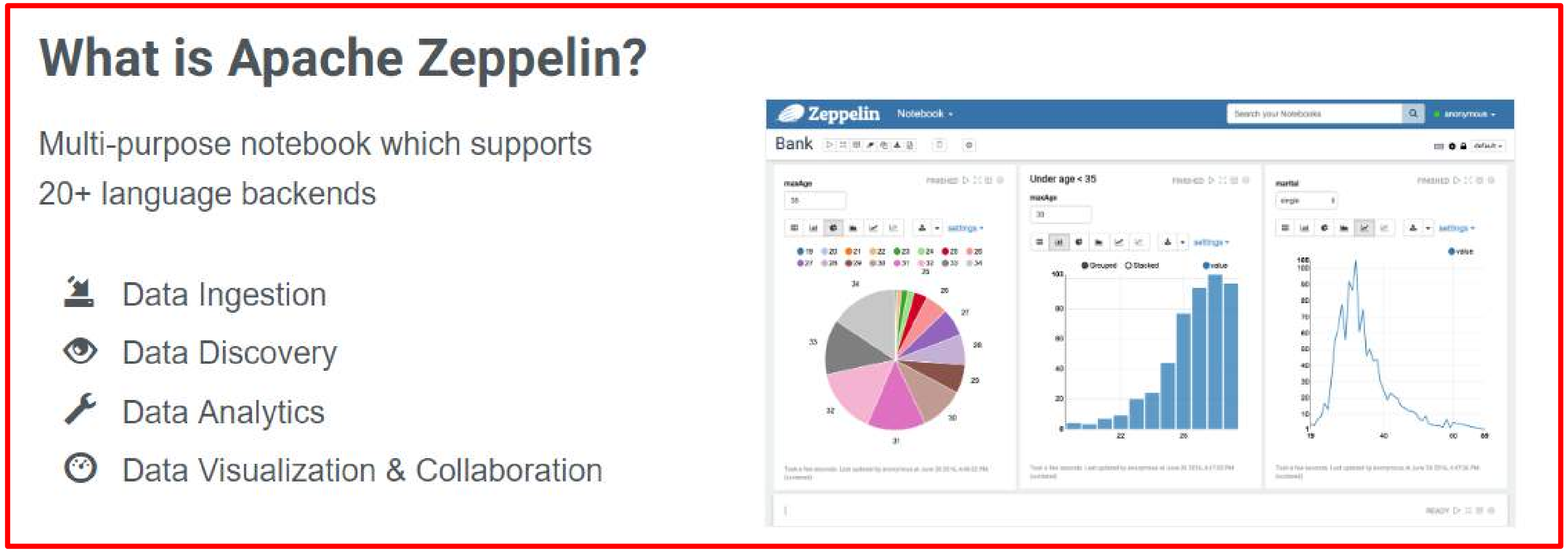
Notebooks supporting Groovy

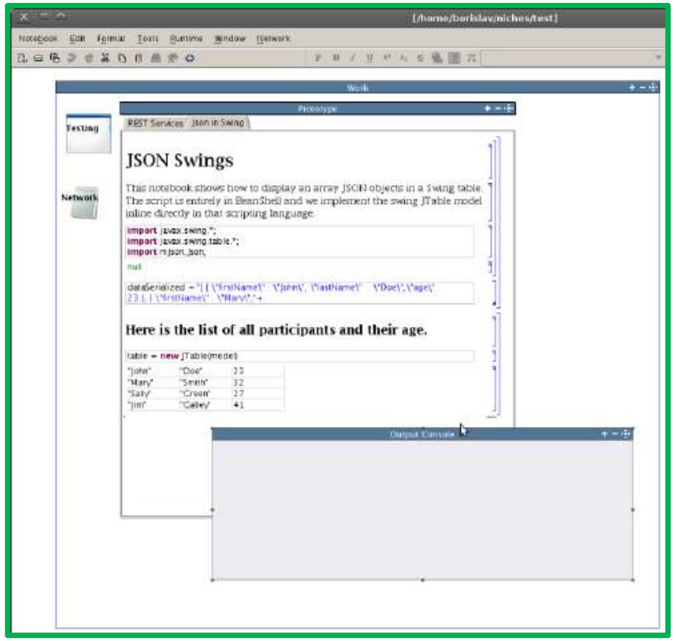
- Jupyter/beakerx
- Apache Zeppelin
- GroovyLab
- Seco

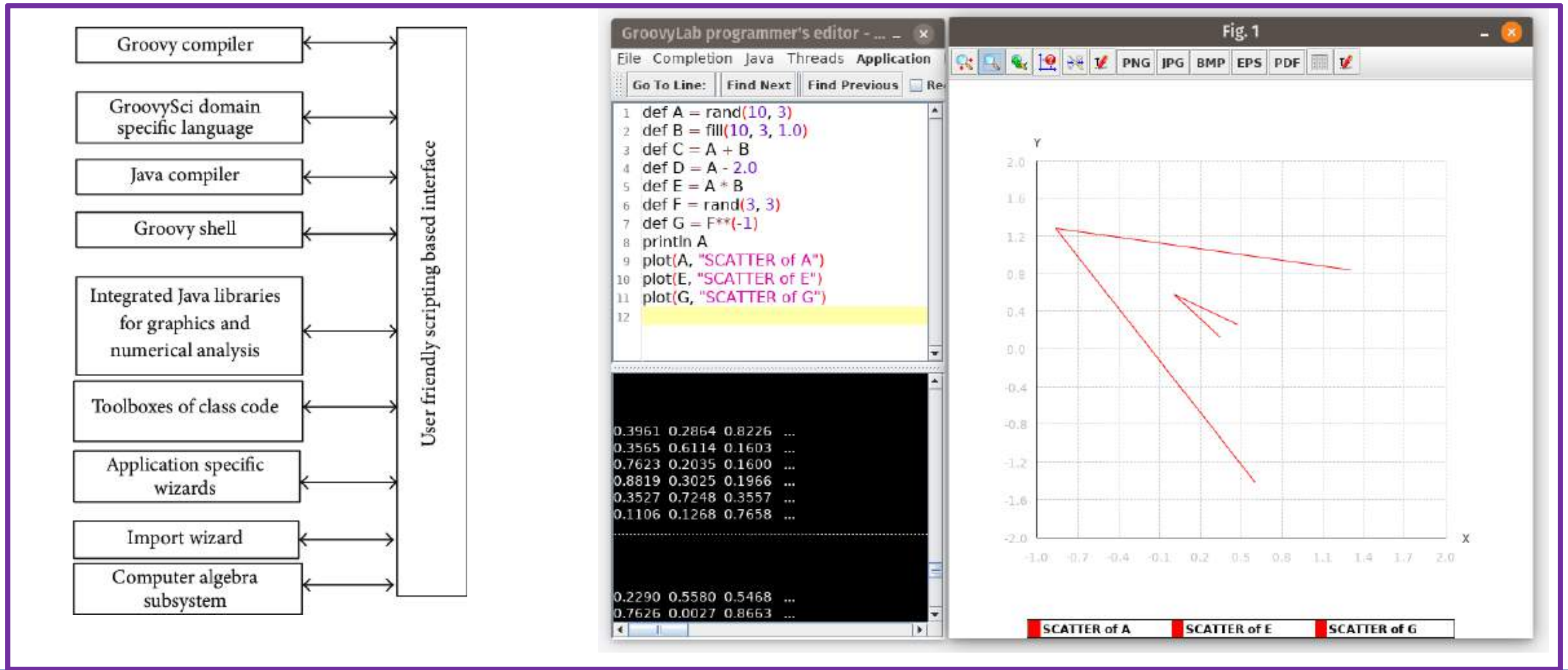


Notebooks supporting Groovy

- Jupyter/beakerx
- Apache Zeppelin
- GroovyLab
- Seco







Data preparation

IO:

- Java in-built
- Groovy enhancements
- Libraries
  - Apache Commons IO https://commons.apache.org/io/
  - AOL Cyclops-React https://github.com/aol/cyclops-react

Web scraping:

- GEB

Batch processing/ETL:

- Spring Batch http://projects.spring.io/spring-batch/
- Apache Camel
- Apache Gobblin

Math libraries

Math and stats libraries

- Java: log, exp, other basic methods.

Libraries:

- Apache Commons Math http://commons.apache.org/math/
  statistics, optimization, and linear algebra
- Apache Mahout http://mahout.apache.org/
  linear algebra, plus distributed linear algebra and machine learning
- JBlas http://jblas.org/ optimized and very fast linear algebra package that uses the BLAS library

Also, many of the machine learning libraries come with some math functionality, often linear algebra, stats, and optimization.

Data storage

Database:

- Java’s JDBC
- Groovy JDBC enhancements and Datasets
- Other NOSQL
  - Apache Cassandra
  - MongoDB
  - Apache CouchDB
  - Neo4j

```
import com.gmongo.GMongo

def db = new GMongo().getDB('athletes')
db.athletes.drop()
db.athletes << [
    first: 'Paul',
    last: 'Tergat', dob: '1969-06-17',
    runs: [[distance: 42195, time: 2 * 60 * 60 + 4 * 60 + 55,
        venue: 'Berlin', when: '2003-09-28’]]
]
```

```
println "World records following $marathon3.venue $marathon3.when:"
def t = new Traversal()
for (Path p in t.description().breadthFirst().
    relationships(MyRelationshipTypes.supercedes).
    evaluator(Evaluators.fromDepth(1)).
    uniqueness(Uniqueness.NONE).
    traverse(marathon3)) {
  def newRecord = p.endNode()
  println "$newRecord.venue $newRecord.when"
}

Graph g = new Neo4jGraph(graphDb)
def pretty = { it.collect { "$it.venue $it.when" }.join(', ') }
def results = []
g.V('venue', 'London').fill(results)
println 'London world records: ' + pretty(results)

results = []
g.V('venue', 'London').in('supercedes').fill(results)
println 'World records after London: ' + pretty(results)
```

Machine learning and data mining

Machine learning and data mining libraries:

- Weka http://www.cs.waikato.ac.nz/ml/weka/
- JavaML http://java-ml.sourceforge.net/
  old and reliable ML library but not actively updated
- Smile http://haifengl.github.io/smile/
  ML library under active development
- JSAT https://github.com/EdwardRaff/JSAT
  contains many machine learning algorithms
- H2O http://www.h2o.ai/
  distributed Java ML framework also supports Scala, R and Python
- Apache Mahout http://mahout.apache.org/
  distributed linear algebra framework
- Apache Spark ml and mllib
  https://github.com/apache/spark/tree/master/examples/src/main/java/org/apache/spark/examples

Neural networks and text processing

Neural networks:

- Encog http://www.heatonresearch.com/encog/
- DeepLearning4j http://deeplearning4j.org/
  natively supports Keras models

Text processing

- Java: StringTokenizer, the java.text package, regular expressions
- Groovy: Regex enhancements, templates, String enhancements
- Libraries:
  - Apache Lucene https://lucene.apache.org/
  - Stanford CoreNLP http://stanfordnlp.github.io/CoreNLP/
  - Apache OpenNLP https://opennlp.apache.org/
  - LingPipe http://alias-i.com/lingpipe/
  - GATE https://gate.ac.uk/
  - MALLET http://mallet.cs.umass.edu/
  - Smile http://haifengl.github.io/smile/

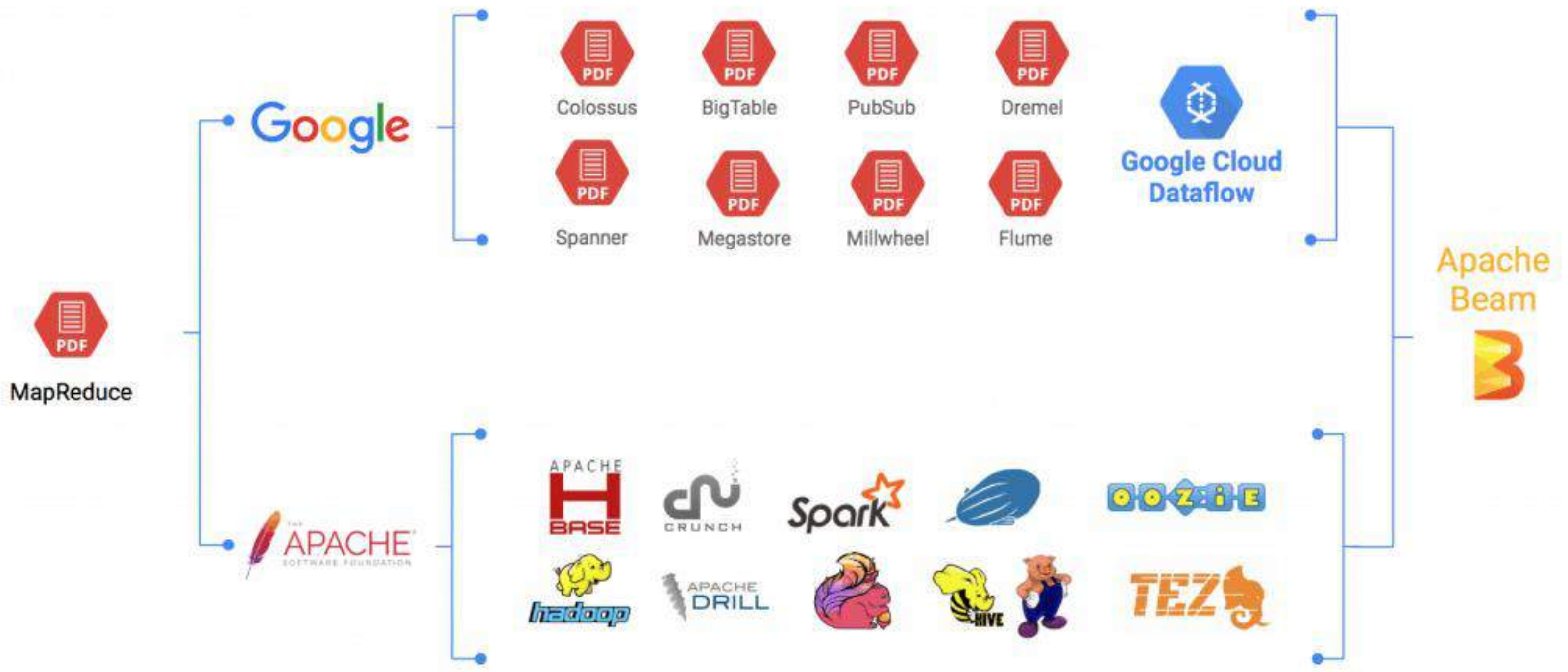
Scaling up

Microservice frameworks:

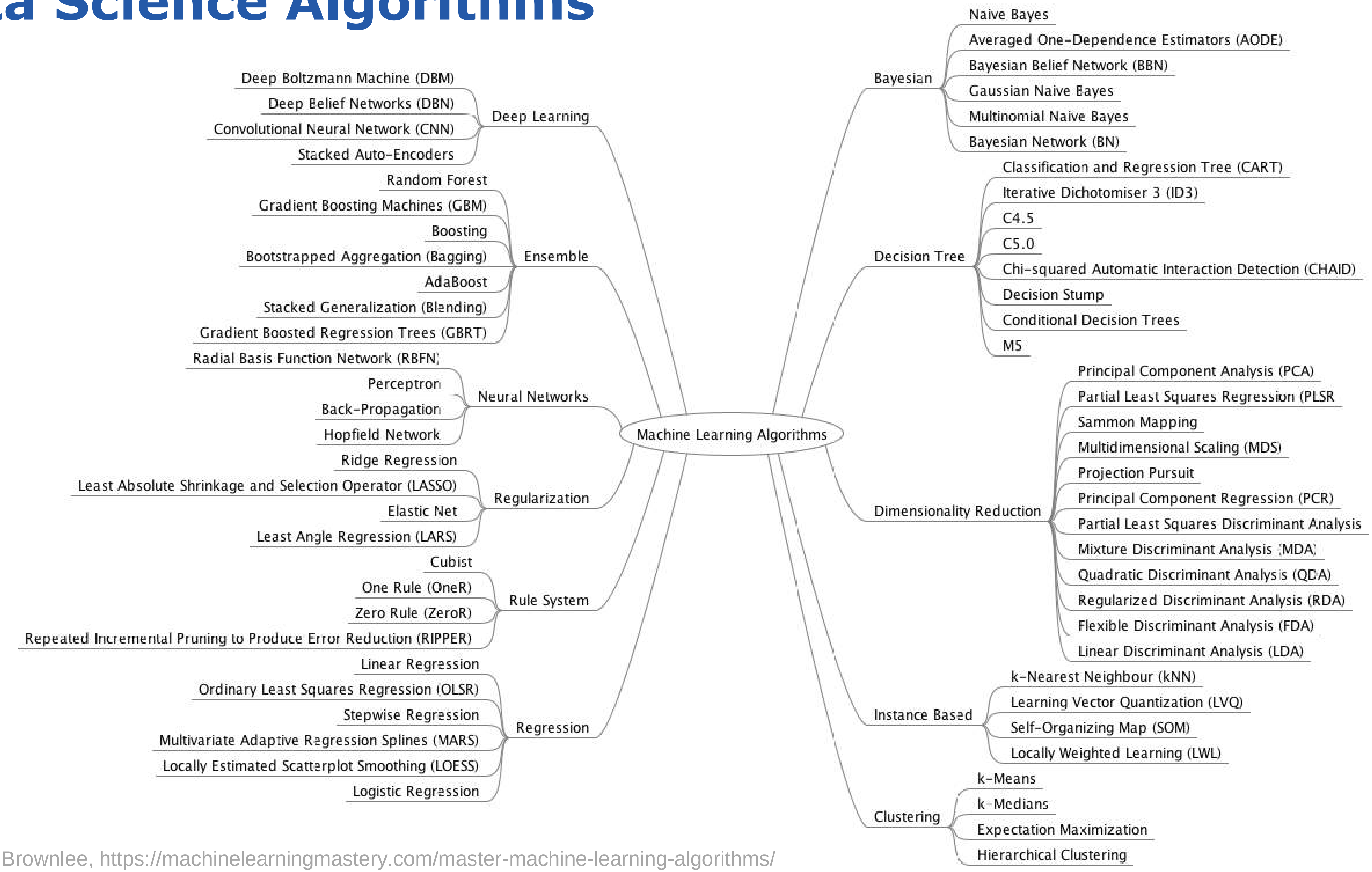
- Micronaut

Distributed data processing:

- Apache Hadoop
- Apache Spark
- Apache Flink
- Apache Samza
- Apache Kafka
- Apache Storm
- Apache Apex
- Apache Beam
- Apache Ignite
- Apache Nifi

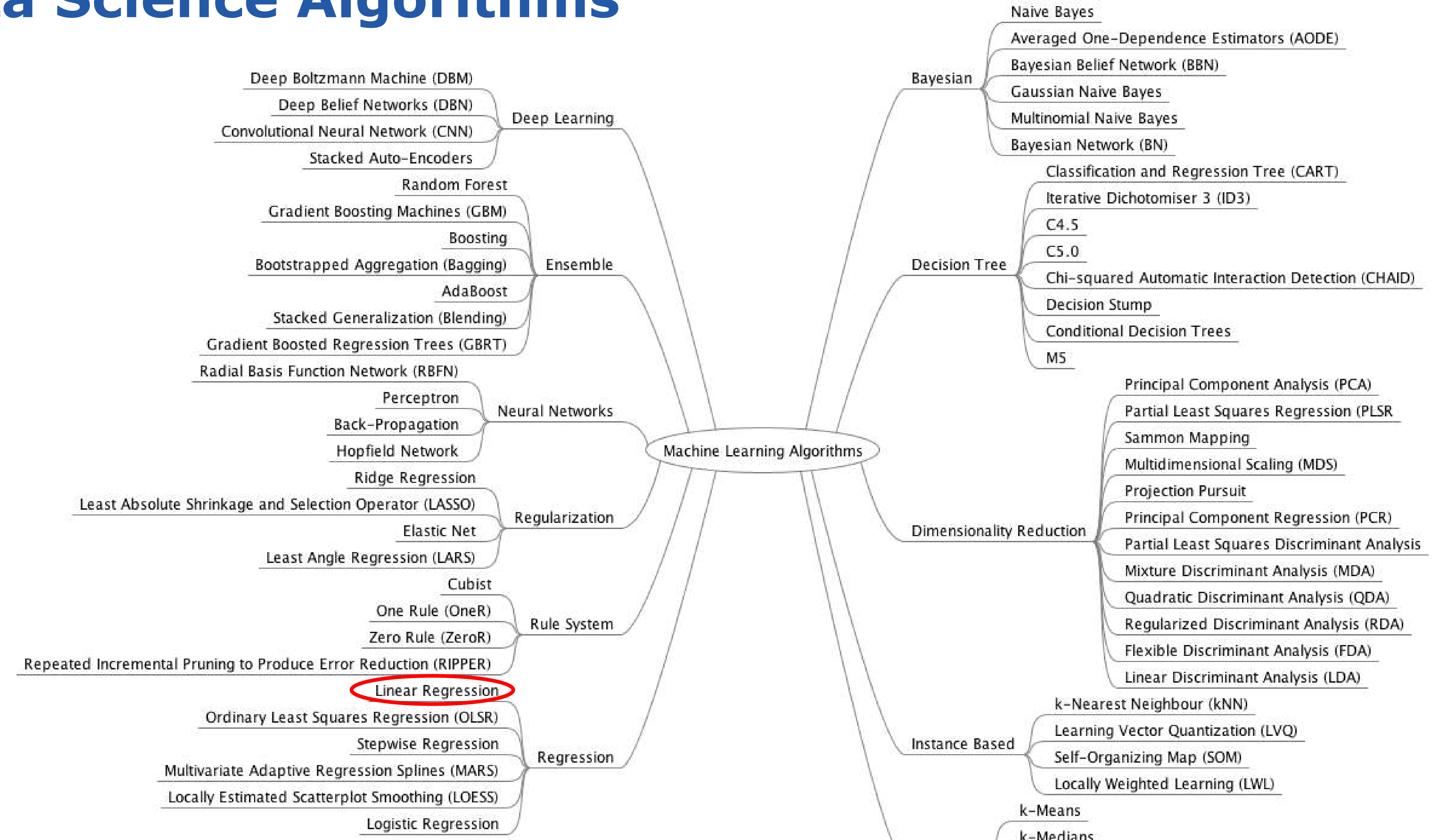


Data Science Algorithms



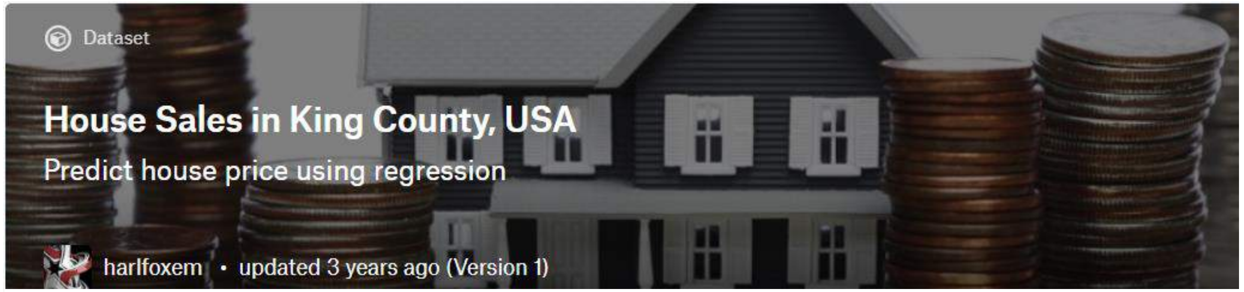
Source: Jason Brownlee, https://machinelearningmastery.com/master-machine-learning-algorithms/

Data Science Algorithms



Source: Jason Brownlee, https://machinelearningmastery.com/master-machine-learning-algorithms/

House price predictions



Usability 8.8

License CC0: Public Domain

Tags finance, home

Description

This dataset contains house sale prices for King County, which includes Seattle. It includes homes sold between May 2014 and May 2015.

It's a great dataset for evaluating simple regression models.

Data (778 KB)

Data Sources

kc_hous... 21.6k x 21

About this file

19 house features plus the price and the id columns, along with 21613 observations.

Dataset: https://www.kaggle.com/harlfoxem/housesalesprediction/
See also: https://nicolai92.github.io/posts/pentaho-weka-prediction

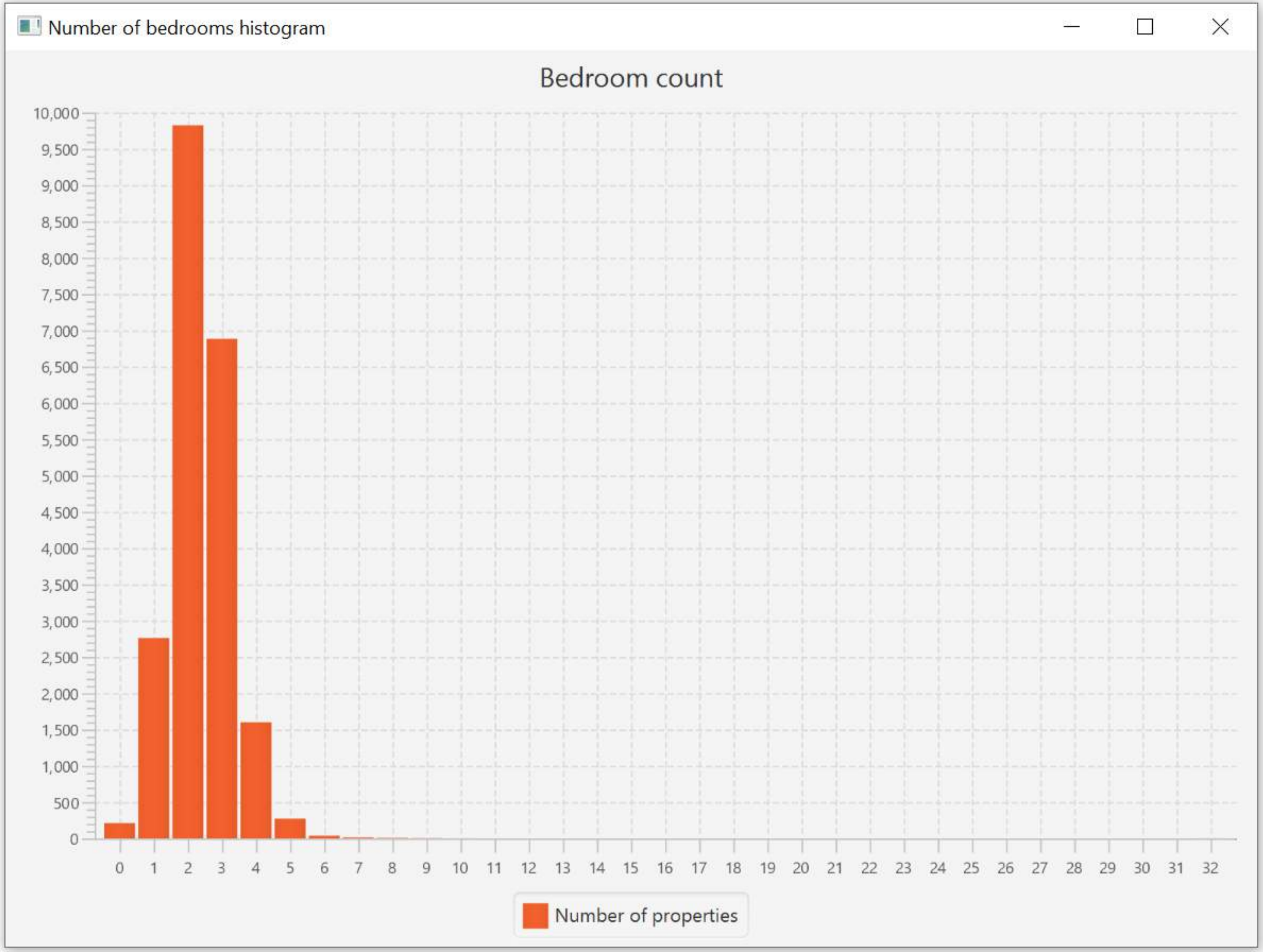
Columns

- # id a notation for a house
- A date Date house was sold
- # price Price is prediction target
- # bedrooms Number of Bedrooms/House
- # bathrooms Number of bathrooms/House
- # sqft_living square footage of the home
- # sqft_lot square footage of the lot
- # floors Total floors (levels) in house
- A waterfront House which has a view to a waterfront
- A view Has been viewed
- A condition How good the condition is (Overall)
- A grade overall grade given to the housing unit, based on King County grading system
- # sqft_above square footage of house apart from basement
- # sqft_basement square footage of the basement
- # yr_built Built Year
- # yr_renovated Year when house was renovated
- # zipcode zip
- # lat Latitude coordinate
- # long Longitude coordinate
- # sqft_living15 Living room area in 2015(implies-- some renovations) This might or might not have affected the lotsize area
- # sqft_lot15 lotSize area in 2015(implies-- some renovations)

House price predictions – view data graphically

```groovy
import org.apache.commons.math3.random.EmpiricalDistribution
import static groovyx.javafx.GroovyFX.start
import static org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
def all  = csv.collect { it.bedrooms.toInteger() }
def dist = new EmpiricalDistribution(all.max()).tap{ load(all as double[]) }
def bins = dist.binStats.withIndex().collectMany { v, i -> [i.toString(), v.n] }

start {
  stage(title: 'Number of bedrooms histogram', show: true, width: 800, height: 600) {
    scene {
      barChart(title: 'Bedroom count', barGap: 0, categoryGap: 2) {
        series(name: 'Number of properties', data: bins)
      }
    }
  }
}
```

House price predictions – view data graphically



House price predictions – view stats

```groovy
import org.apache.commons.math3.stat.descriptive.SummaryStatistics
import static org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
def all  = csv.collect { it.bedrooms.toInteger() }

def stats = new SummaryStatistics()
all.each{ stats.addValue(it as double) }
println stats.summary
```

```
n: 21613
min: 0.0
max: 33.0
mean: 3.370841623097218
std dev: 0.930061831147451
variance: 0.8650150097573497
sum: 72854.0
```

House price predictions – investigate outliers

```
import org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
csv.findAll{ it.bedrooms.toInteger() > 10 }.each{ println it.toMap() as TreeMap }
```

[bathrooms:3, **bedrooms:11**, condition:3, date:20140821T000000, floors:2, grade:7, id:1773100755, lat:47.556, long:-122.363, price:520000, sqft_above:2400, sqft_basement:600, sqft_living:3000, sqft_living15:1420, sqft_lot:4960, sqft_lot15:4960, view:0, waterfront:0, yr_built:1918, yr_renovated:1999, zipcode:98106]
[bathrooms:1.75, **bedrooms:33**, condition:5, date:20140625T000000, floors:1, grade:7, id:2402100895, lat:47.6878, long:-122.331, price:640000, sqft_above:1040, sqft_basement:580, sqft_living:1620, sqft_living15:1330, sqft_lot:6000, sqft_lot15:4700, view:0, waterfront:0, yr_built:1947, yr_renovated:0, zipcode:98103]

House price predictions – investigate outliers

opencsv

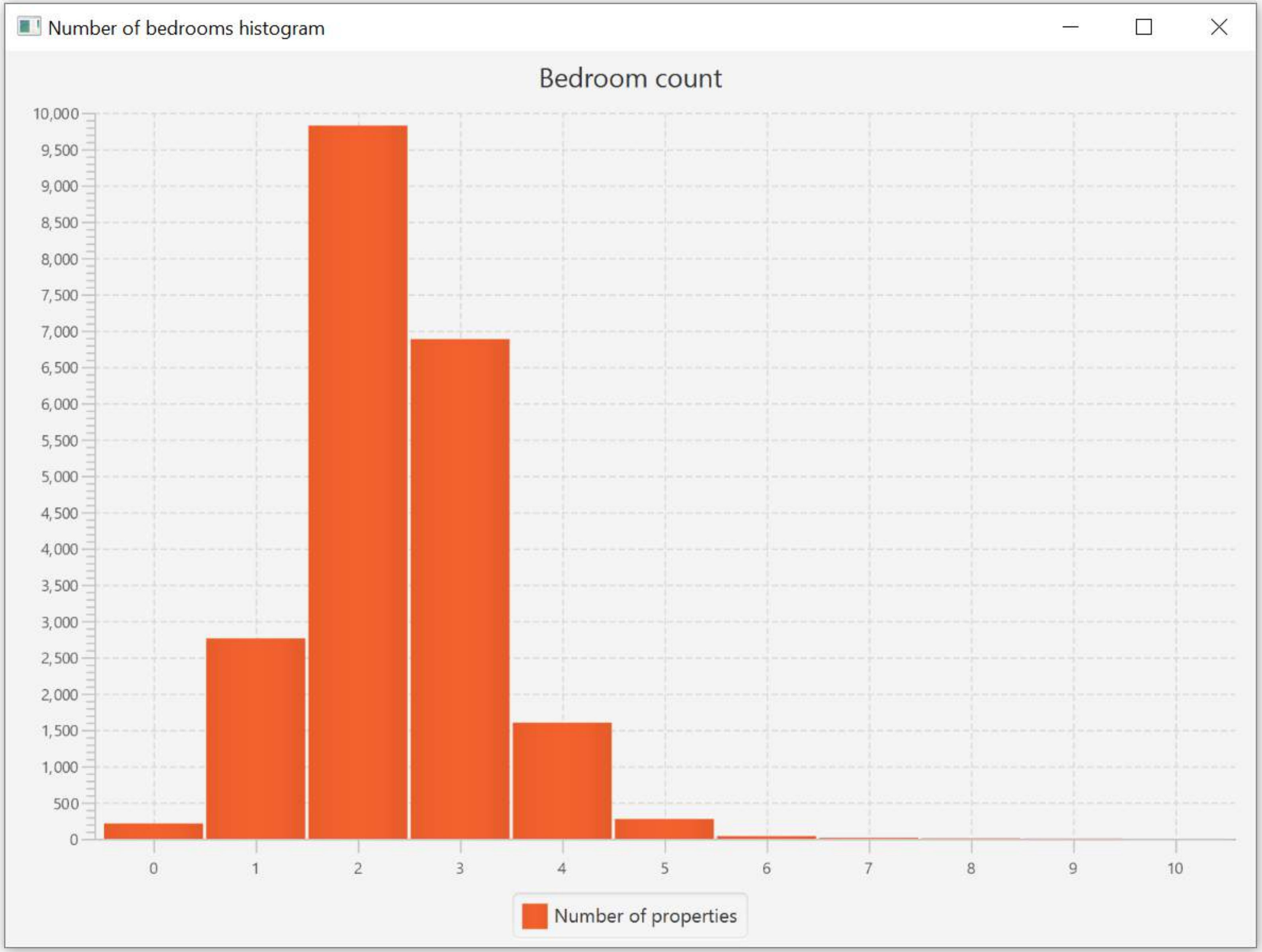
```
import com.opencsv.bean.*
import groovy.transform.ToString

@ToString(includeNames = true)
class House {
    @CsvBindByName
    Integer bedrooms

    @CsvBindByName
    String bathrooms

    @CsvBindByName(column = 'sqft_lot')
    Integer area_lot
}

def file    = 'kc_house_data.csv' as File
def builder = new CsvToBeanBuilder(new FileReader(file))
def records = builder.withType(House).build().parse()

records.findAll{ it.bedrooms > 10 }.each{ println it }
```

```
House(bedrooms:11, bathrooms:3, area_lot:4960)
House(bedrooms:33, bathrooms:1.75, area_lot:6000)
```

House price predictions – remove outlier and view

```
import org.apache.commons.math3.random.EmpiricalDistribution
import static groovyx.javafx.GroovyFX.start
import static org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
def all  = csv.collect { it.bedrooms.toInteger() }.findAll{ it < 30 }
def dist = new EmpiricalDistribution(all.max()).tap{ load(all as double[]) }
def bins = dist.binStats.withIndex().collectMany { v, i -> [i.toString(), v.n] }

start {
  stage(title: 'Number of bedrooms histogram', show: true, width: 800, height: 600) {
    scene {
      barChart(title: 'Bedroom count', barGap: 0, categoryGap: 2) {
        series(name: 'Number of properties', data: bins)
      }
    }
  }
}
```

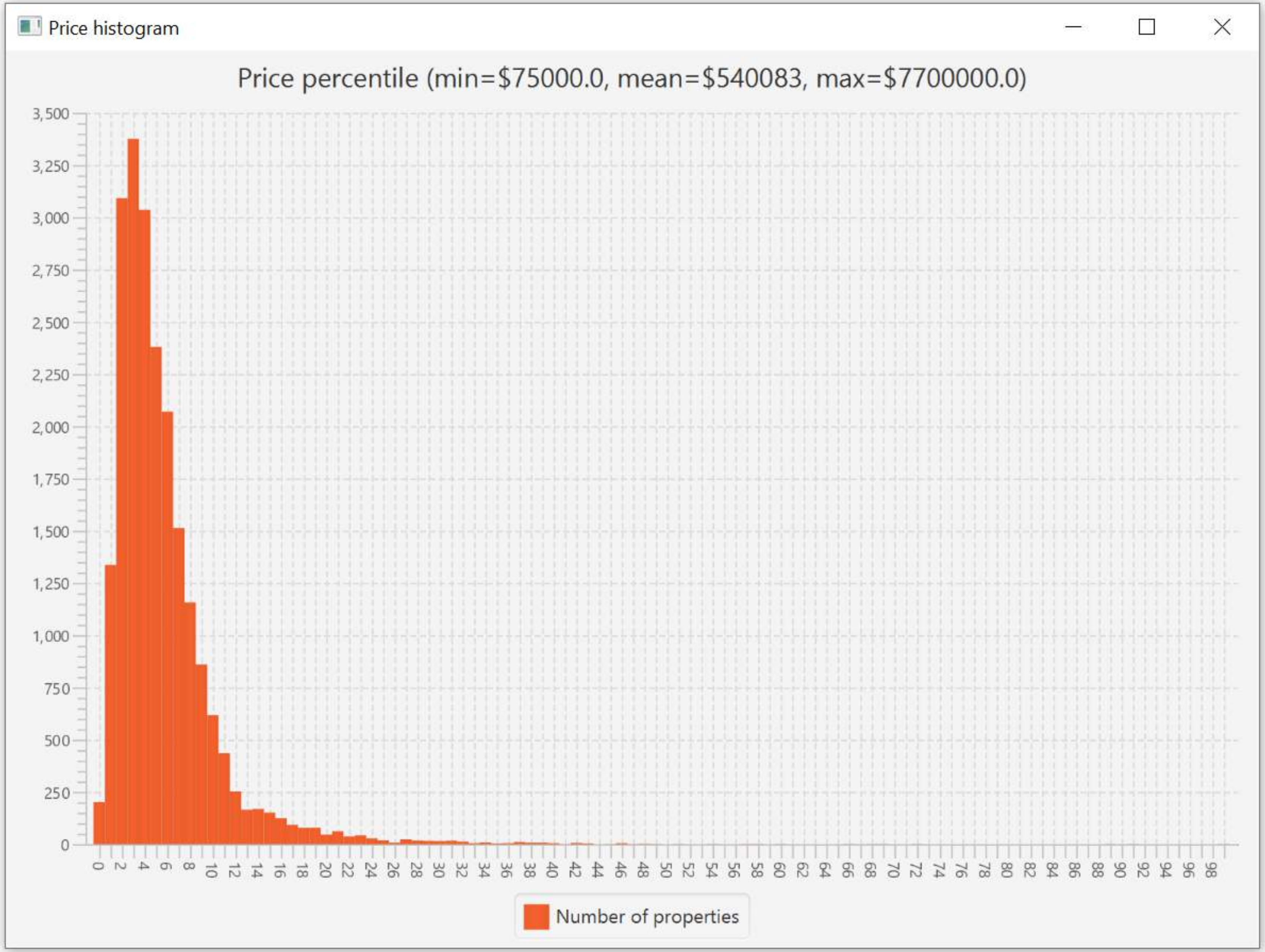
House price predictions – remove outlier and view



House price predictions – remove outlier and view

```
import org.apache.commons.math3.random.EmpiricalDistribution
import static groovyx.javafx.GroovyFX.start
import static org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
def all  = csv.findAll { it.bedrooms.toInteger() < 30 }.collect { it.price.toDouble() }
def info = new SummaryStatistics(); all.each(info::addValue)
def head = "Price percentile (min=\$$info.min, mean=\$${info.mean as int}, max=\$$info.max)"
def dist = new EmpiricalDistribution(100).tap{ load(all as double[]) }
def bins = dist.binStats.withIndex().collectMany { v, i -> [i.toString(), v.n] }

start {
  stage(title: 'Price histogram', show: true, width: 800, height: 600) {
    scene {
      barChart(title: head, barGap: 0, categoryGap: 0) {
        series(name: 'Number of properties', data: bins)
      }
    }
  }
}
```

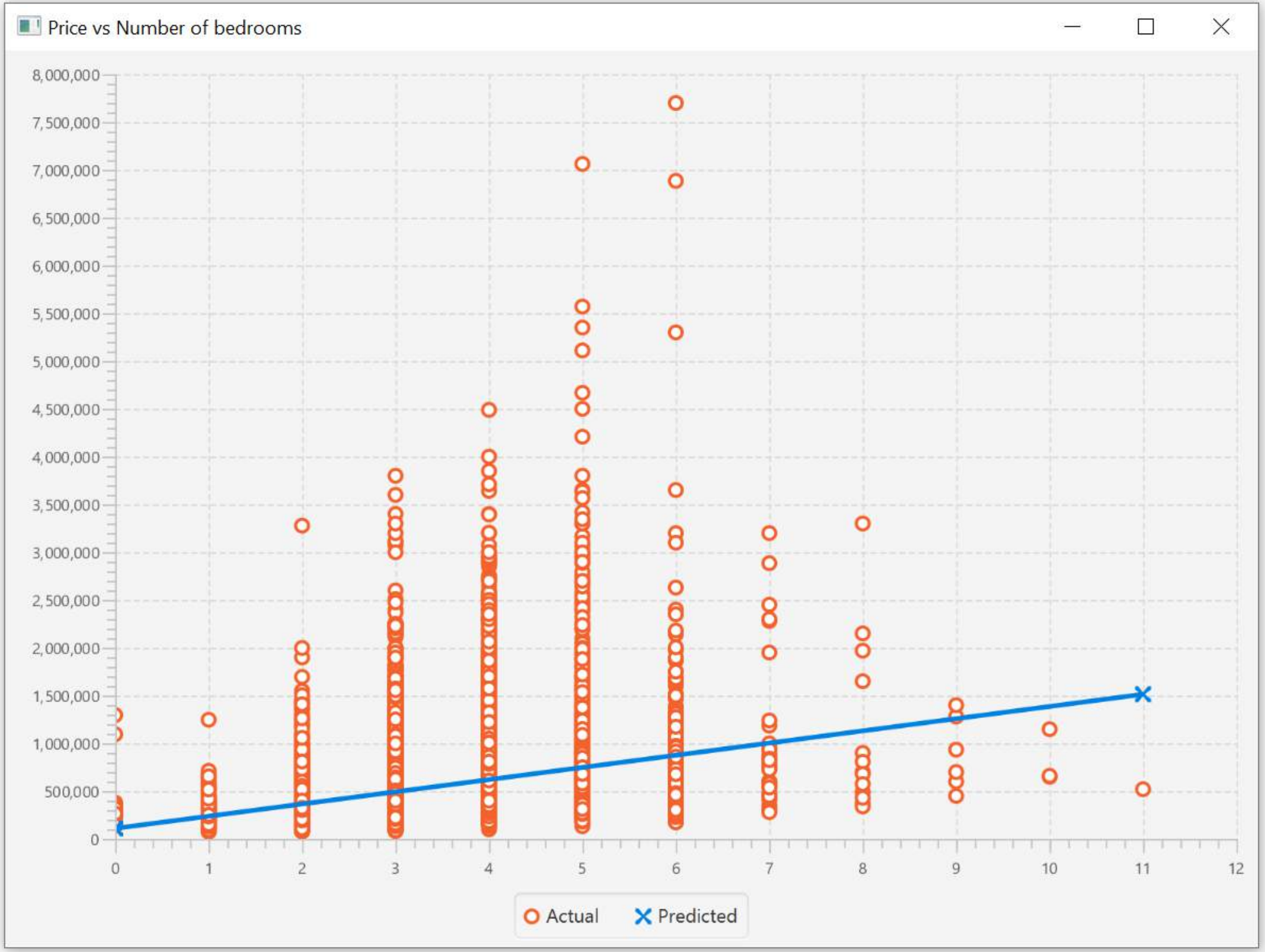
House price predictions – remove outlier and view



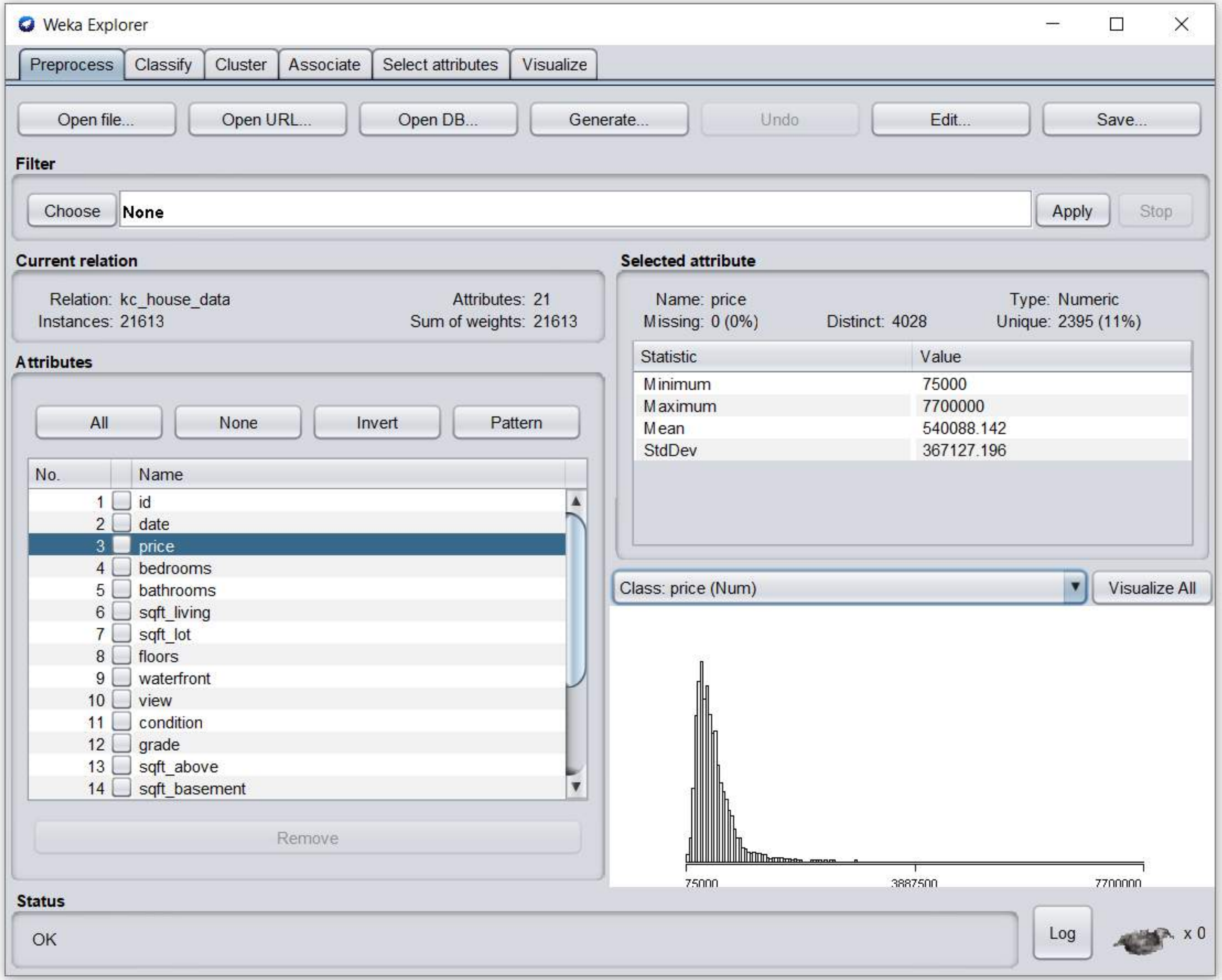
House price predictions – linear regression

```
import org.apache.commons.math3.stat.regression.SimpleRegression
import static groovyx.javafx.GroovyFX.start
import static org.apache.commons.csv.CSVFormat.RFC4180 as CSV

def file = 'kc_house_data.csv' as File
def csv  = CSV.withFirstRecordAsHeader().parse(new FileReader(file))
def all  = csv.collect { [it.bedrooms.toDouble(), it.price.toDouble()] }.findAll{ it[0] < 30 }

def reg          = new SimpleRegression().tap{ addData(all as double[][]) }
def (minB, maxB) = [all.min{ it[0] }[0], all.max{ it[0] }[0]]
def predicted    = [[minB, reg.predict(minB)], [maxB, reg.predict(maxB)]]

start {
    stage(title: 'Price vs Number of bedrooms', show: true, width: 800, height: 600) {
        scene {
            scatterChart {
                series(name: 'Actual', data: all)
            }
            lineChart {
                 series(name: 'Predicted', data: predicted)
            }
        }
    }
}
```

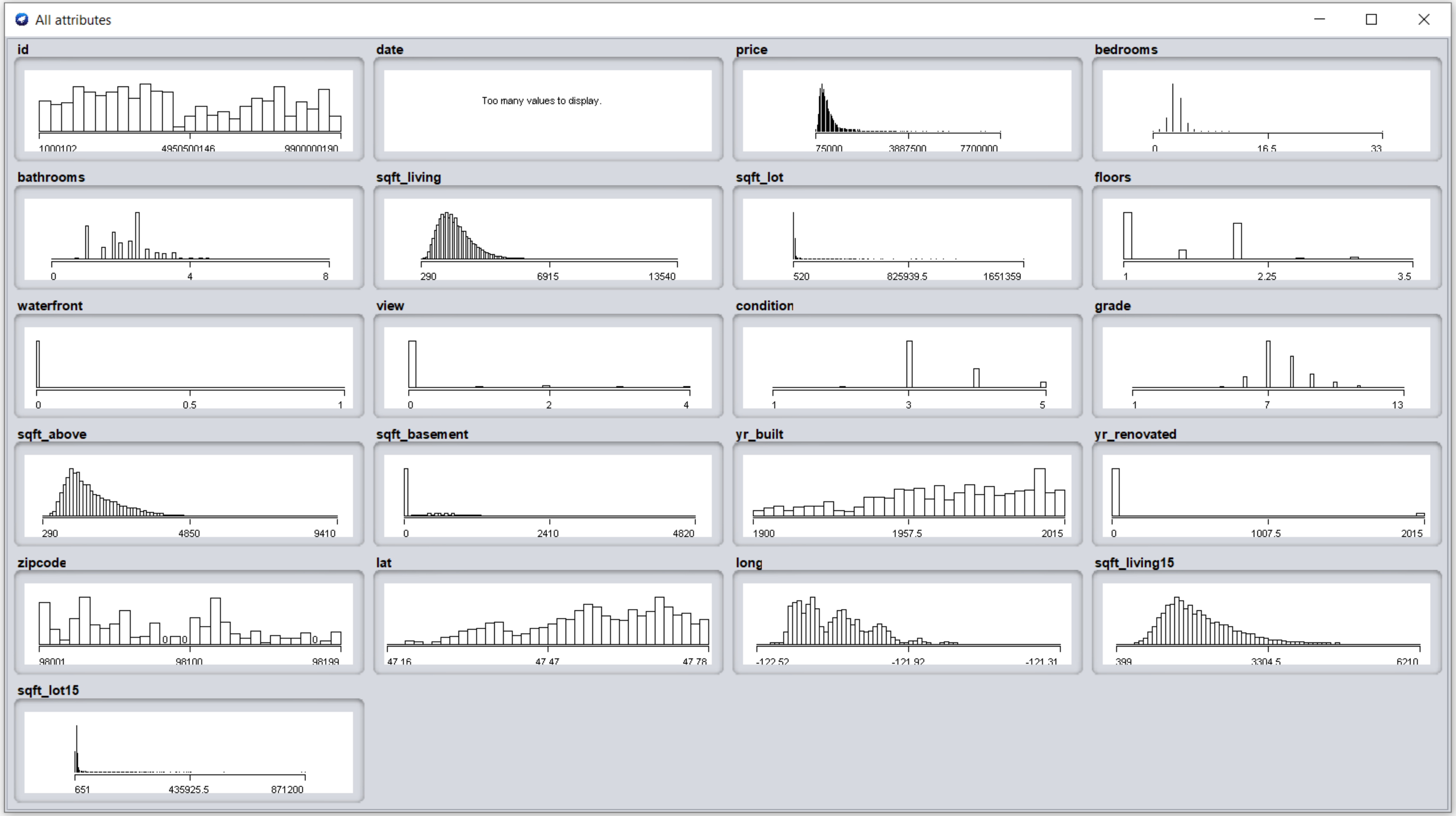
House price predictions – linear regression



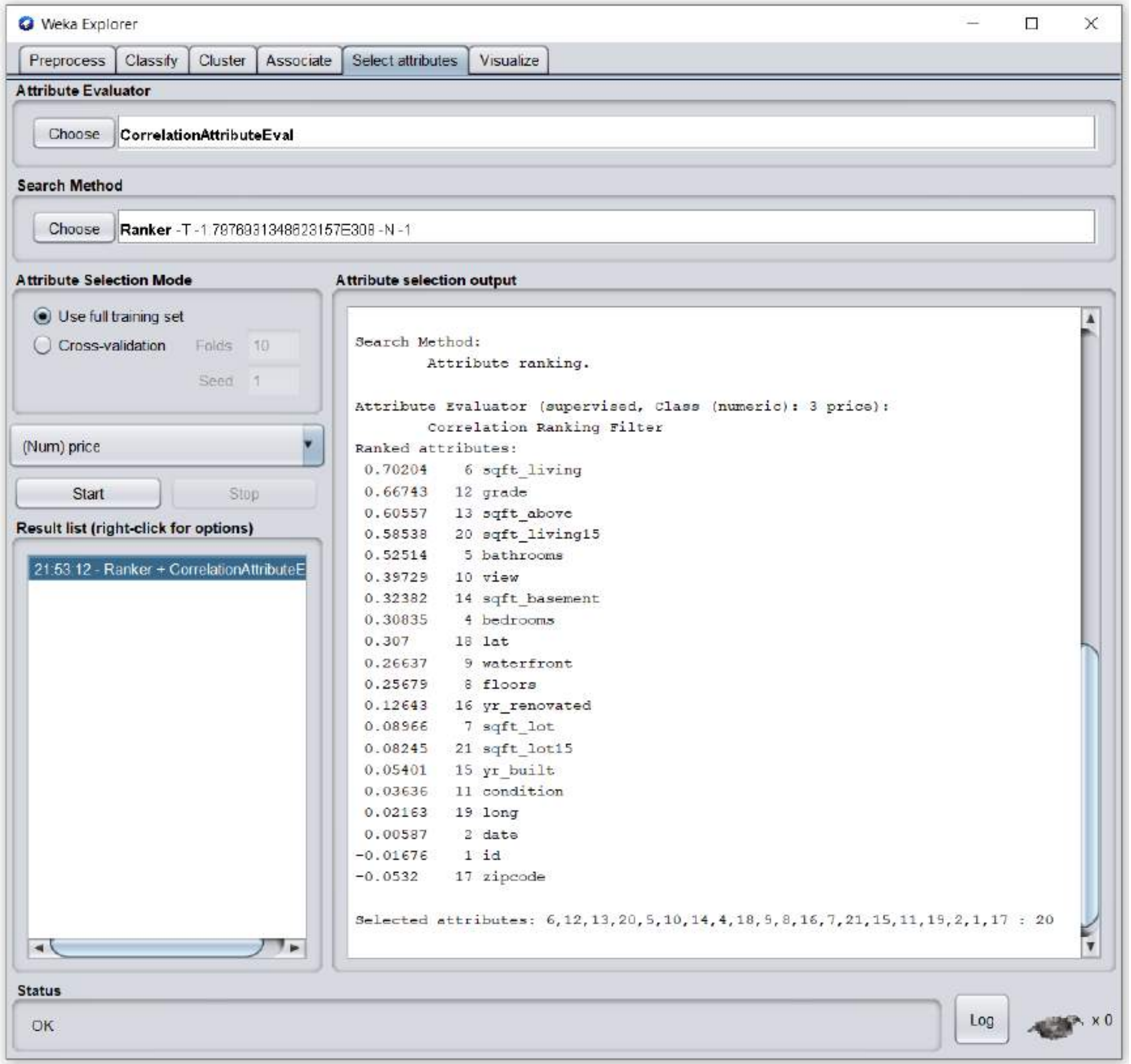
House price predictions - Weka

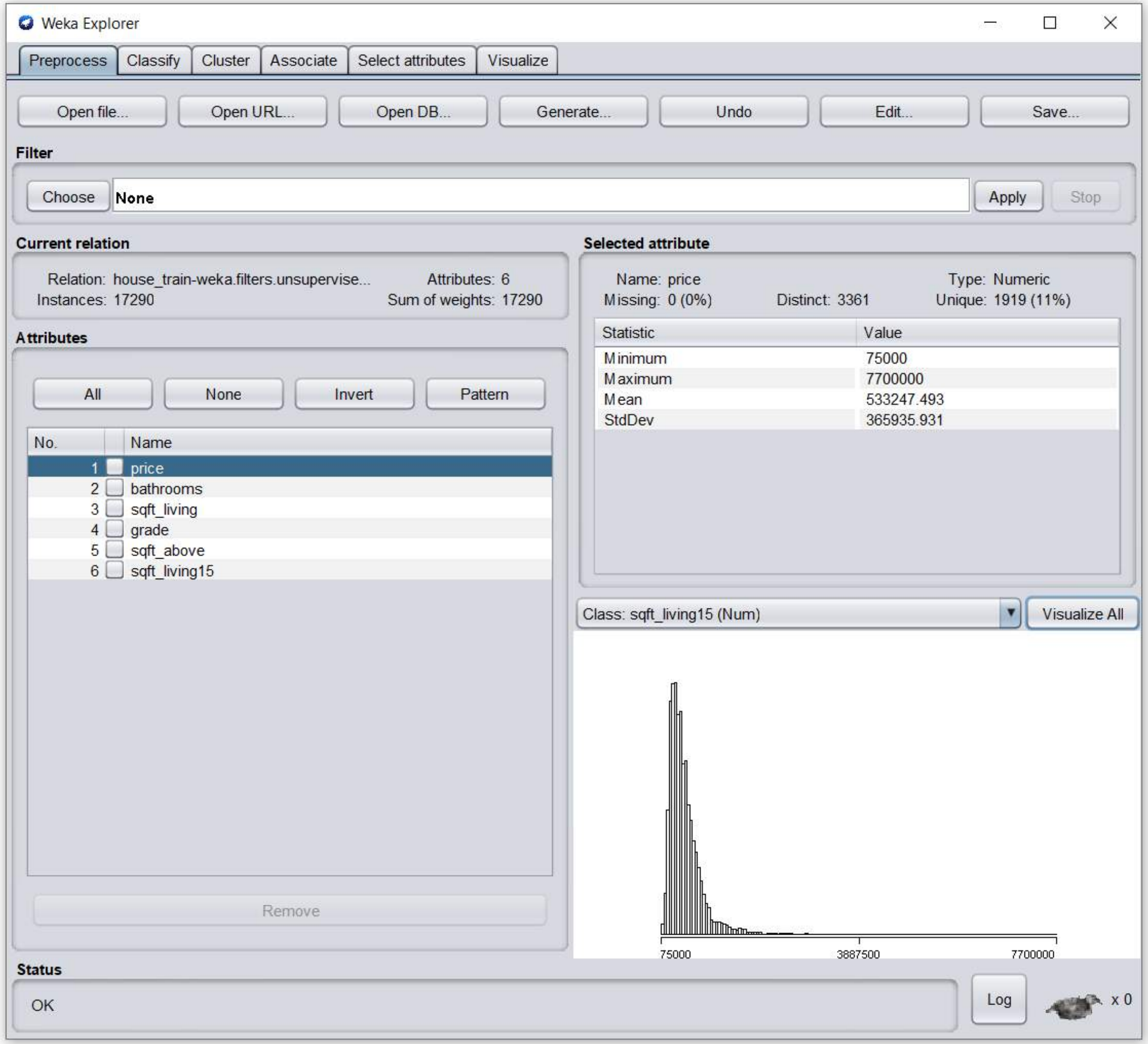


House price predictions

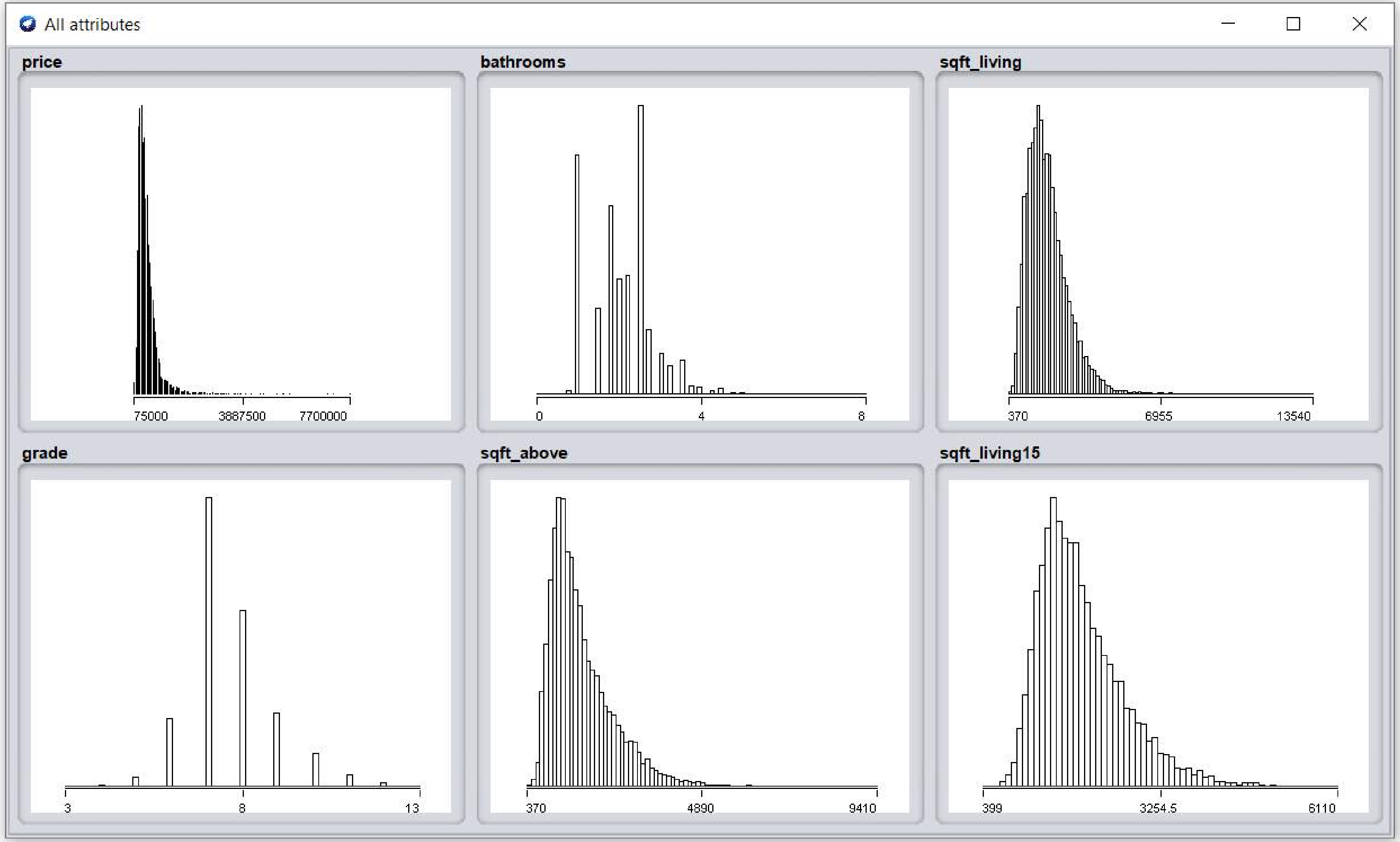


House price predictions

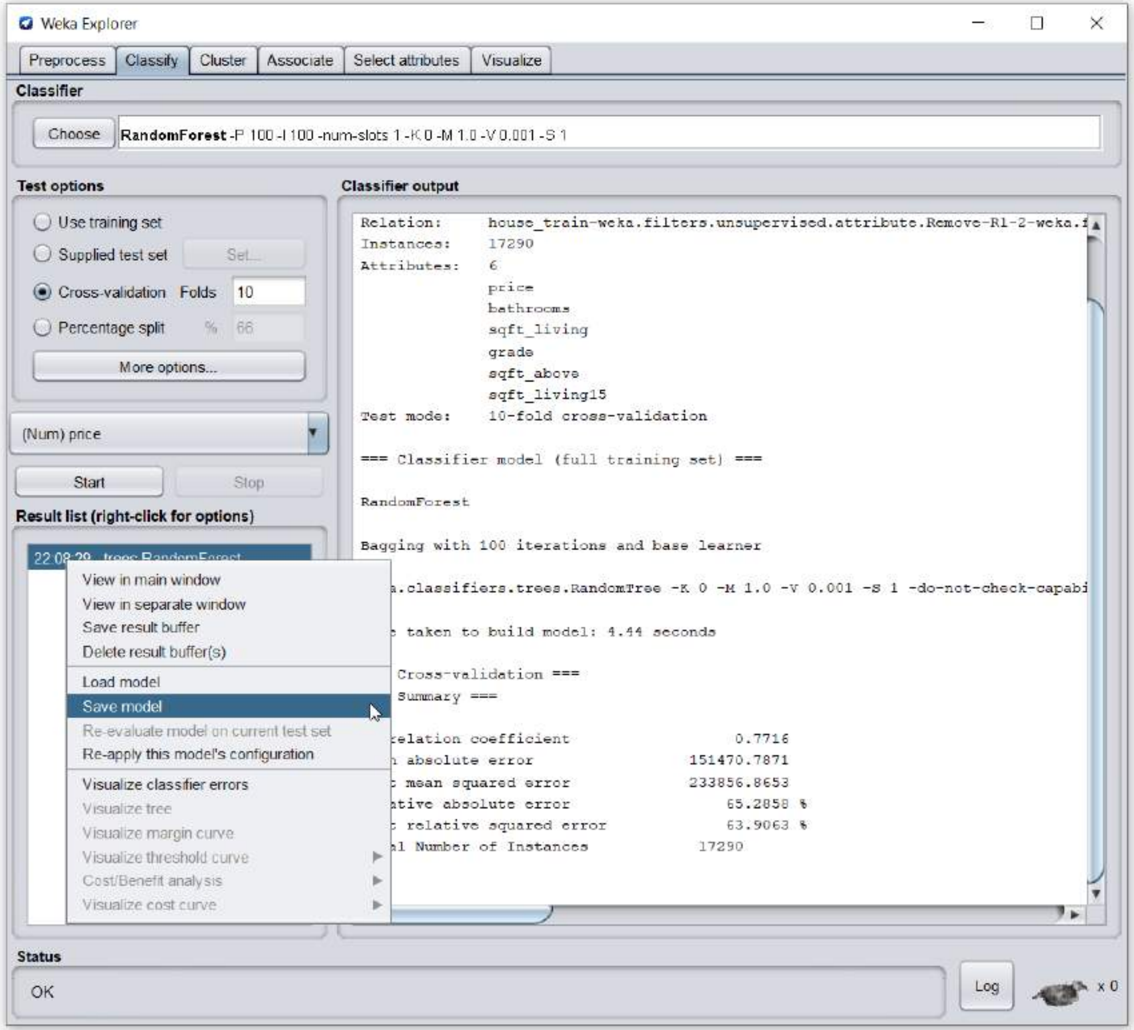


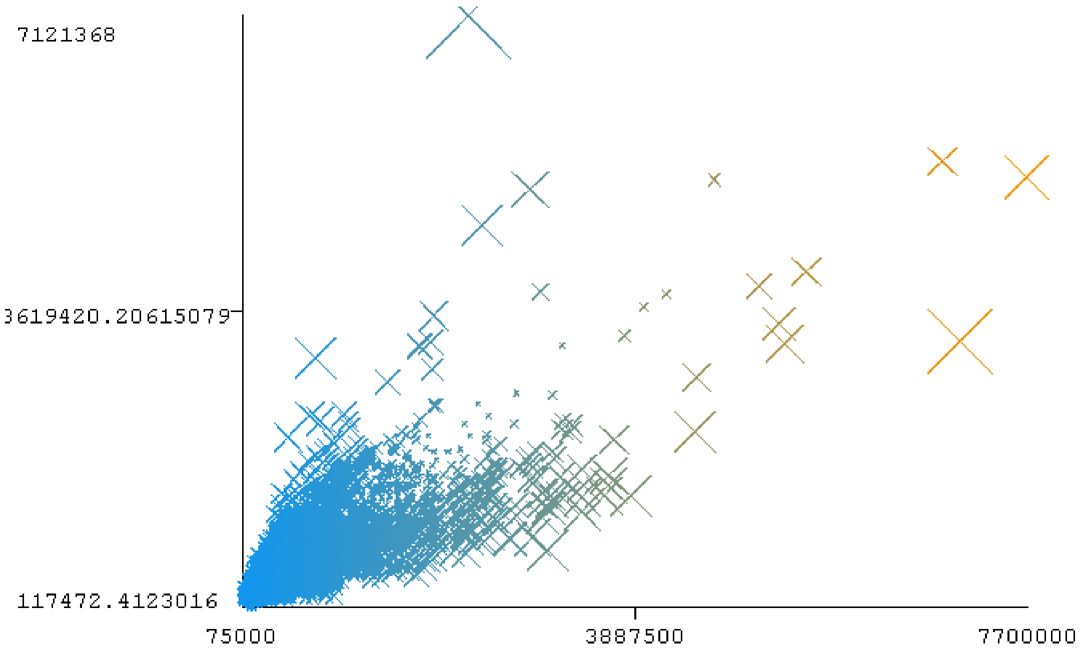


House price predictions



House price predictions

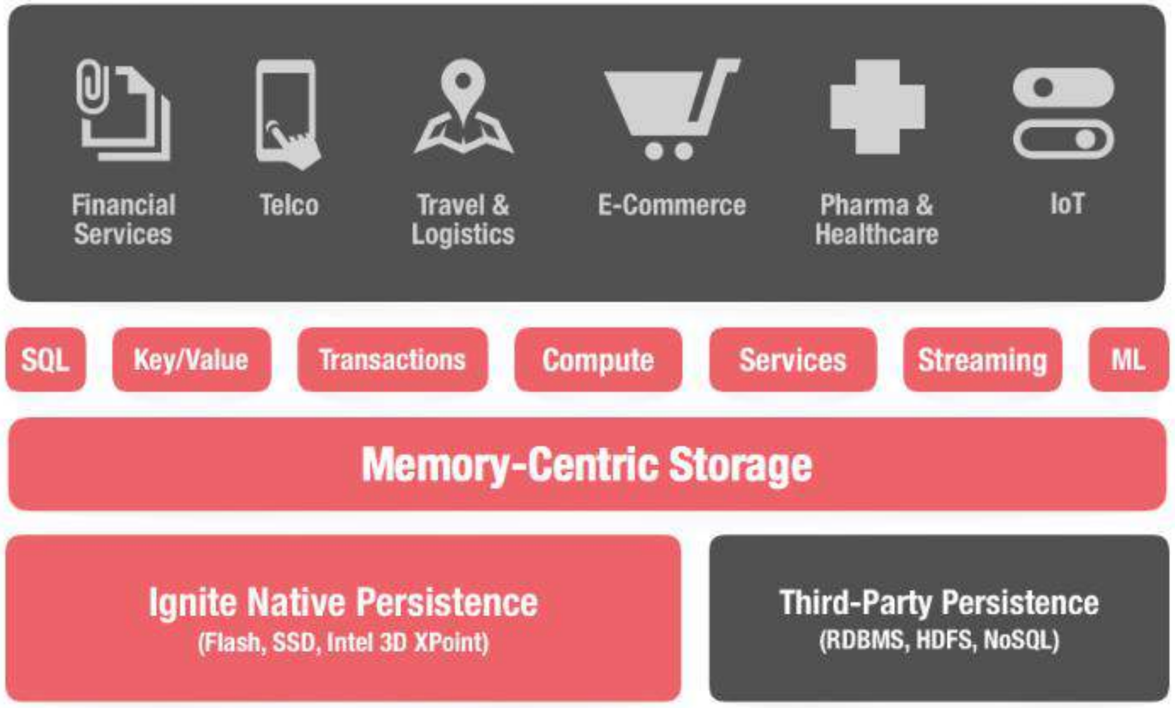


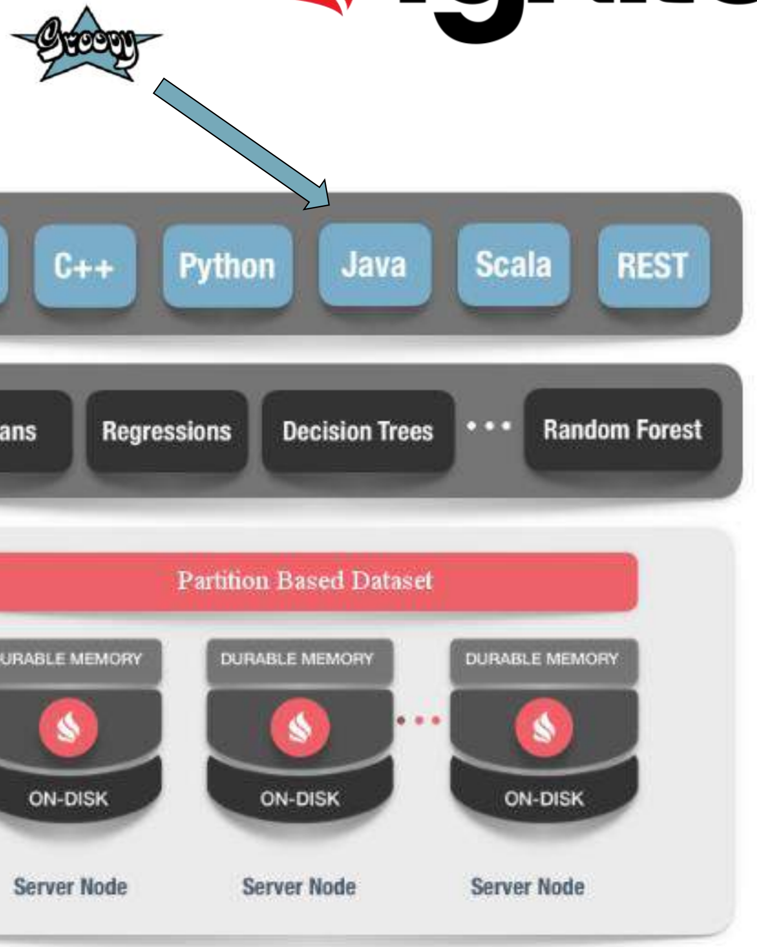


House price predictions – split dataset

```
def full = getClass().classLoader.getResource('kc_house_data.csv').file as File
def parent = full.parentFile
def lines = full.readLines()
def (trainLines, testLines) = lines.chop(lines.size() * 0.8 as int, -1)

def train = new File(parent, 'house_train.csv')
train.text = trainLines.join('\n')

def test = new File(parent, 'house_test.csv')
test.delete()
test << lines[0] << '\n' << testLines.join('\n')
```

Scaling up





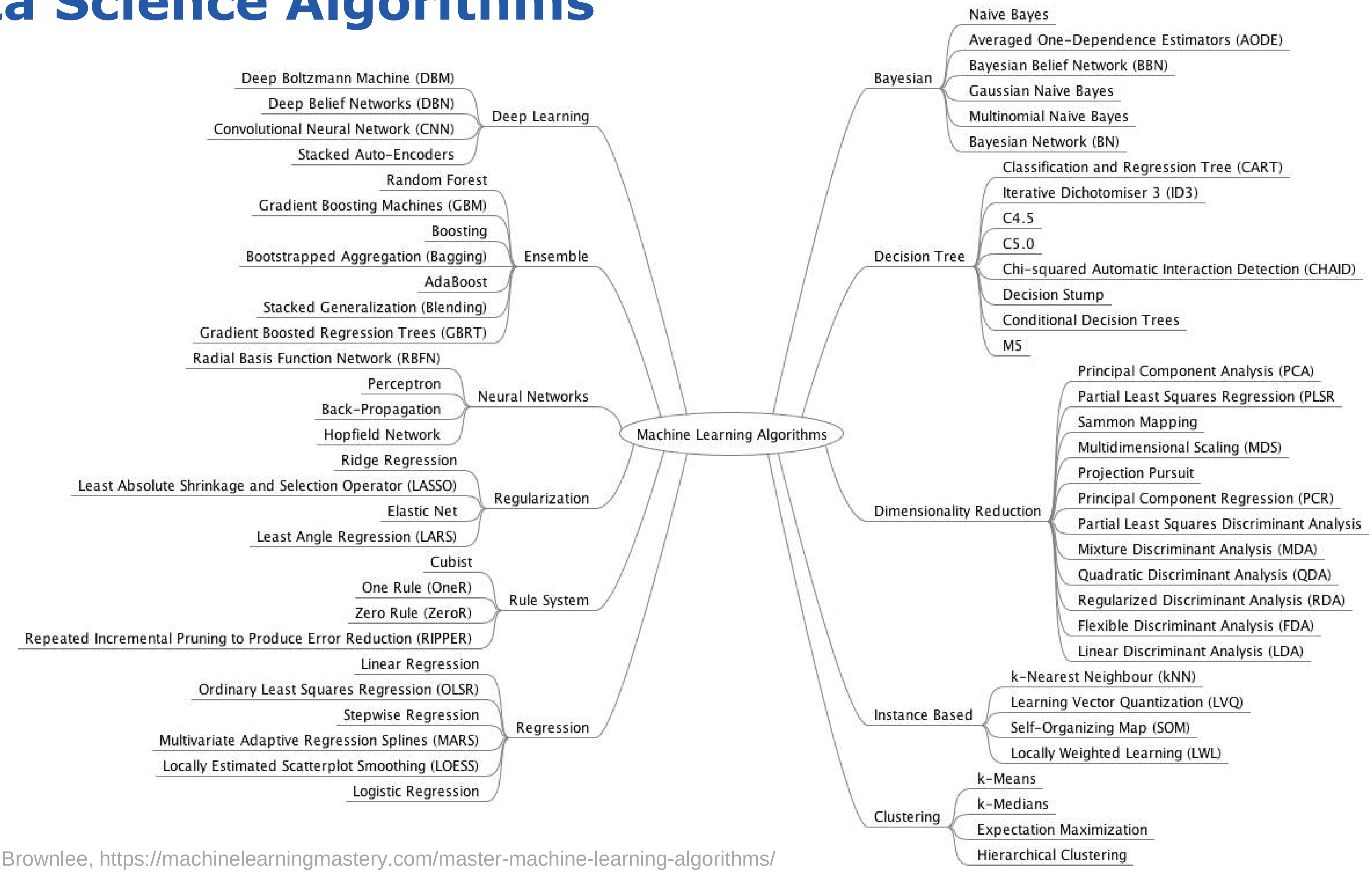
https://github.com/apache/ignite/blob/master/examples/src/main/java/org/apache/ignite/examples/ml/regression/linear/BostonHousePricesPredictionExample.java

House price predictions – linear regression

```
Ignite ignite = Ignition.start("/path/to/example-ignite.xml")
ignite.withCloseable {
    println ">>> Ignite grid started."
    def dataCache = new SandboxMLCache(ignite).fillCacheWith(BOSTON_HOUSE_PRICES)
    def trainer = new LinearRegressionLSQRTrainer()
            .withEnvironmentBuilder(defaultBuilder().withRNGSeed(0))
    def vectorizer = new DummyVectorizer().labeled(Vectorizer.LabelCoordinate.FIRST)
    def split = new TrainTestDatasetSplitter().split(0.8)
    def mdl = trainer.fit(ignite, dataCache, split.trainFilter, vectorizer)
    def metric = new RegressionMetrics().withMetric { it.r2() }
    def score = Evaluator.evaluate(dataCache, split.testFilter, mdl, vectorizer, metric)

    println ">>> Model: " + toString(mdl)
    println ">>> R^2 score: " + score
    dataCache.destroy()
}

static toString(mdl) {
    def sign = { val -> val < 0 ? '- ' : '+ ' }
    def valIdx = { idx, val -> sprintf '%.2f*f%d', val, idx }
    def valIdxSign = { idx, val -> sign(val) + valIdx(idx, Math.abs(val)) }
    def valSign = { val -> sign(val) + sprintf('%.2f', Math.abs(val)) }
    def w = mdl.weights
    def i = mdl.intercept
    def result = [valIdx(0, w.get(0)), *(1..<w.size()).collect{ valIdxSign(it, w.get(it)) }, valSign(i)]
    result.join(' ')
}
```

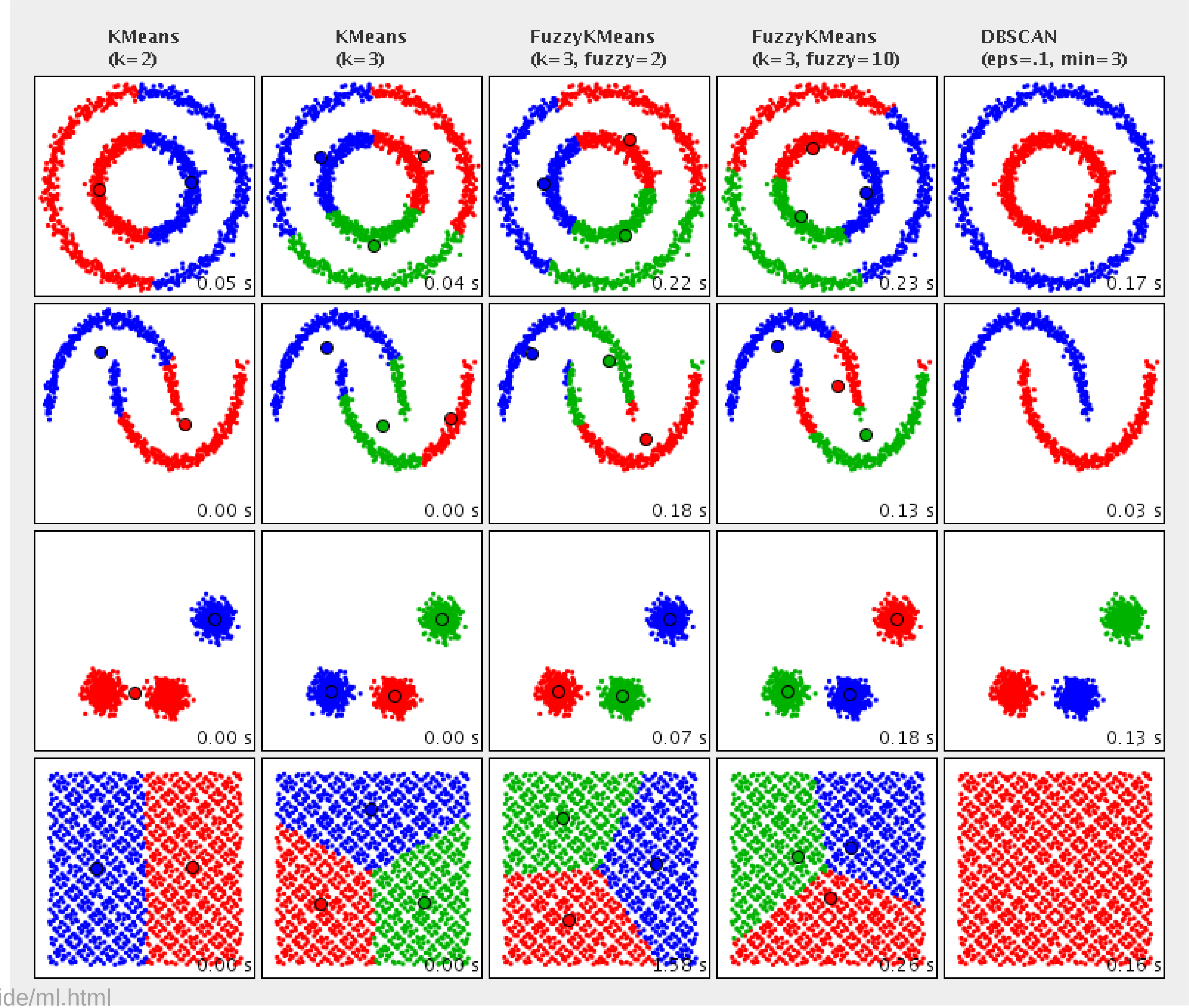
```
[09:17:59] Ignite node started OK (id=0b9592e1)
[09:17:59] Topology snapshot [ver=1, locNode=0b9592e1, servers=1, clients=0,
state=ACTIVE, CPUs=12, offheap=6.4GB, heap=7.1GB]
>>> Ignite grid started.
>>> Model: 0.04*f0 - 0.05*f1 - 0.79*f2 - 10.01*f3 + 0.28*f4 + 0.01*f5 -
0.89*f6 + 0.54*f7 - 0.00*f8 - 0.18*f9 - 0.01*f10 + 0.09*f11 - 0.15*f12 + 14.10
>>> R^2 score: 0.412878309612252
[09:17:59] Ignite node stopped OK [uptime=00:00:00.626]
```

Data Science Algorithms



Source: Jason Brownlee, https://machinelearningmastery.com/master-machine-learning-algorithms/

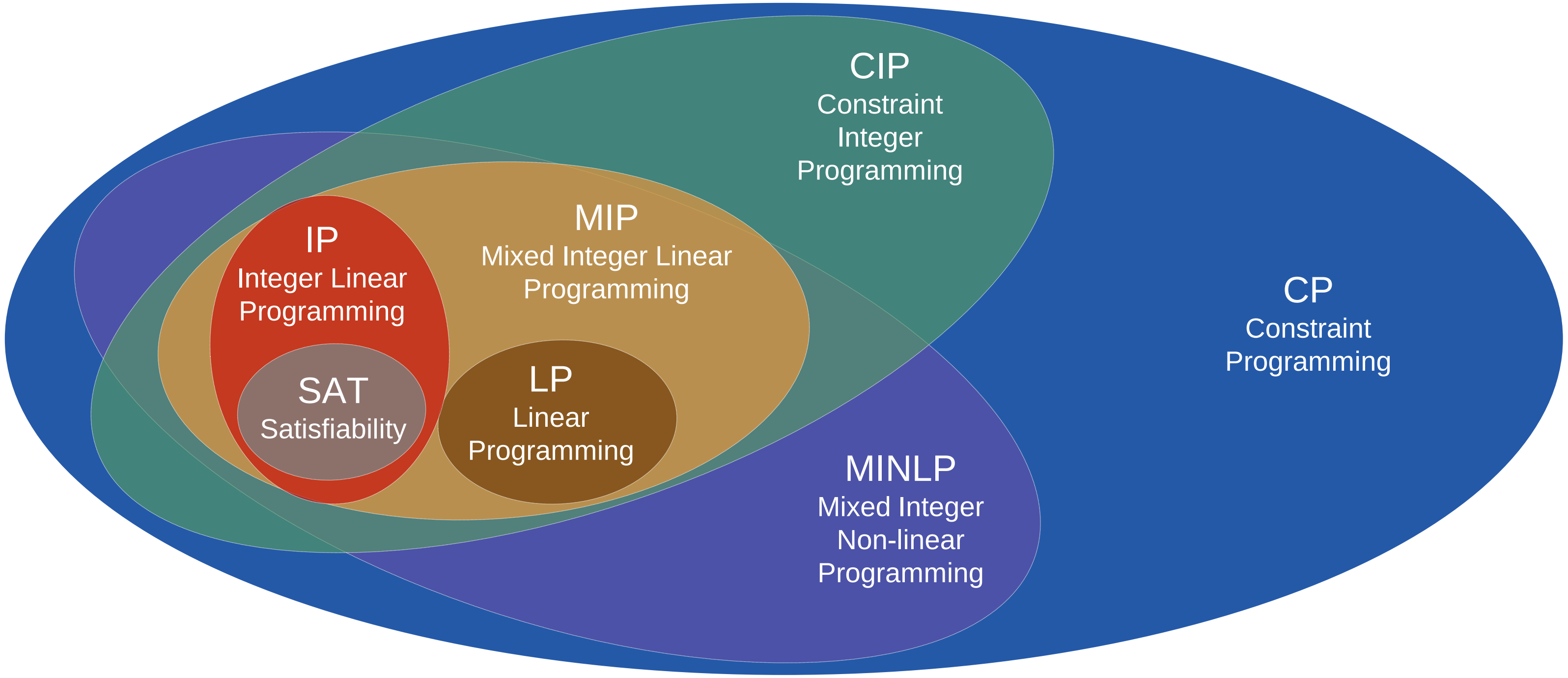
Data Science Algorithms: Classification



https://commons.apache.org/proper/commons-math/userguide/ml.html

Computational problems in Computer Science

- Kinds: decision problems, search problems, counting problems, optimization problems
- Paradigms: brute force, divide & conquer, search & enumerate, randomized, complexity reduction, recursive, back tracking, graph
- Optimization approaches: linear programming, dynamic programming, greedy, heuristics



Constraint Programming

Where is it used?

- Factory/assembly line scheduling
- Workforce management/scheduling (call centres, aircraft crew, etc)
- Vehicle routing/traffic planning/traffic management
- Packing problems
- Timetabling (exams, lectures, trains, gate arrival at airports)
- Configuration and design
- Supertree construction (bioinformatics)
- Network design (telecommunications)
- Military logistics (air cover for naval fleet)
- Aircraft maintenance schedules
- Recruitment (personnel selection)
- Financial trading systems
- Language detection
- Operations research

Constraint Programming

Typical domains:

- boolean domains, where only true/false constraints apply (SAT problem)
- integer domains
- rational domains
- interval domains, in particular for scheduling problems
- linear domains, where only linear functions are described and analyzed (although approaches to non-linear problems do exist)
- finite domains, where constraints are defined over finite sets
- mixed domains, involving two or more of the above

Cryptarithmetic

```
      S E N D
+     M O R E
=   M O N E Y
```

Replace the letters with decimal digits to make a valid arithmetic sum

Cryptarithmetic: Brute force

```
def solutions():
    # letters = ('s', 'e', 'n', 'd', 'm', 'o', 'r', 'y')
    all_solutions = list()
    for s in range(1, 10):
        for e in range(0, 10):
            for n in range(0, 10):
                for d in range(0, 10):
                    for m in range(1, 10):
                        for o in range(0, 10):
                            for r in range(0, 10):
                                for y in range(0, 10):
                                    if len({s, e, n, d, m, o, r, y}) == 8:
                                        send = 1000 * s + 100 * e + 10 * n + d
                                        more = 1000 * m + 100 * o + 10 * r + e
                                        money = 10000 * m + 1000 * o + 100 * n + 10 * e + y

                                        if send + more == money:
                                            all_solutions.append((send, more, money))
    return all_solutions

print(solutions())
```

```
  S E N D
+ M O R E
= M O N E Y
```

```
[(9567, 1085, 10652)]
```

Cryptarithmetic: Brute force

```
    S E N D
+   M O R E
= M O N E Y
```

```
def solutions() {
    // letters = ['s', 'e', 'n', 'd', 'm', 'o', 'r', 'y']
    def all_solutions = []
    for (s in 1..<10)
        for (e in 0..9)
            for (n in 0..9)
                for (d in 0..9)
                    for (m in 1..9)
                        for (o in 0..9)
                            for (r in 0..9)
                                for (y in 0..9)
                                    if ([s, e, n, d, m, o, r, y].toSet().size() == 8) {
                                        def send = 1000 * s + 100 * e + 10 * n + d
                                        def more = 1000 * m + 100 * o + 10 * r + e
                                        def money = 10000 * m + 1000 * o + 100 * n + 10 * e + y
                                        if (send + more == money)
                                            all_solutions.add([send, more, money])
                                    }
    return all_solutions
}

print(solutions())
```

```
[[9567, 1085, 10652]]
```

Cryptarithmetic: Brute force

```
from itertools import permutations

def solution2():
    letters = ('s', 'e', 'n', 'd', 'm', 'o', 'r', 'y')
    digits = range(10)
    for perm in permutations(digits, len(letters)):
        sol = dict(zip(letters, perm))
        if sol['s'] == 0 or sol['m'] == 0:
            continue
        send = 1000 * sol['s'] + 100 * sol['e'] + 10 * sol['n'] + sol['d']
        more = 1000 * sol['m'] + 100 * sol['o'] + 10 * sol['r'] + sol['e']
        money = 10000 * sol['m'] + 1000 * sol['o'] + 100 * sol['n'] + 10 * sol['e'] + sol['y']
        if send + more == money:
            return send, more, money

print(solution2())
```

```
    S E N D
+   M O R E
= M O N E Y
```

```
(9567, 1085, 10652)
```

Cryptarithmetic: Brute force

```
def solution2() {
    def digits = 0..9
    for (p in digits.permutations()) {
        if (p[-1] < p[-2]) continue
        def (s, e, n, d, m, o, r, y) = p
        if (s == 0 || m == 0)
            continue
        def send = 1000 * s + 100 * e + 10 * n + d
        def more = 1000 * m + 100 * o + 10 * r + e
        def money = 10000 * m + 1000 * o + 100 * n + 10 * e + y
        if (send + more == money)
            return [send, more, money]
    }
}

print(solution2())
```

```
    S E N D
+   M O R E
= M O N E Y
```

```
[9567, 1085, 10652]
```

Cryptarithmetic: Constraint programming

```
from csp import Constraint, CSP
from typing import Dict, List, Optional


class SendMoreMoneyConstraint(Constraint[str, int]):
    def __init__(self, letters: List[str]) -> None:
        super().__init__(letters)
        self.letters: List[str] = letters

    def satisfied(self, assignment: Dict[str, int]) -> bool:
        # not a solution if duplicate values
        if len(set(assignment.values())) < len(assignment):
            return False

        # if all vars assigned, check if correct
        if len(assignment) == len(self.letters):
            s: int = assignment["S"]
            e: int = assignment["E"]
            n: int = assignment["N"]
            d: int = assignment["D"]
            m: int = assignment["M"]
            o: int = assignment["O"]
            r: int = assignment["R"]
            y: int = assignment["Y"]
            send: int = s * 1000 + e * 100 + n * 10 + d
            more: int = m * 1000 + o * 100 + r * 10 + e
            money: int = m * 10000 + o * 1000 + n * 100 + e * 10 + y
            return send + more == money

        return True
…
```

```
      S E N D
+     M O R E
=   M O N E Y
```

```
…
letters = ["S", "E", "N", "D", "M", "O", "R", "Y"]
possible_digits = {}
for letter in letters:
     possible_digits[letter] = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
possible_digits["M"] = [1]  # can't start with 0 constraint
csp: CSP[str, int] = CSP(letters, possible_digits)
csp.add_constraint(SendMoreMoneyConstraint(letters))
solution: Optional[Dict[str, int]] = csp.backtracking_search()
if solution is None:
    print("No solution found!")
else:
    print(solution)
```

```
{'S': 9, 'E': 5, 'N': 6, 'D': 7,
'M': 1, 'O': 0, 'R': 8, 'Y': 2}
```

Adapted from: https://freecontent.manning.com/constraint-satisfaction-problems-in-python/

Cryptarithmetic: Constraint programming

```
@Grab('org.choco-solver:choco-solver:4.10.0')
import org.chocosolver.solver.Model
import org.chocosolver.solver.variables.IntVar

def model = new Model("SEND+MORE=MONEY")
def S = model.intVar("S", 1, 9)
def E = model.intVar("E", 0, 9)
def N = model.intVar("N", 0, 9)
def D = model.intVar("D", 0, 9)
def M = model.intVar("M", 1, 9)
def O = model.intVar("O", 0, 9)
def R = model.intVar("R", 0, 9)
def Y = model.intVar("Y", 0, 9)

model.allDifferent(S, E, N, D, M, O, R, Y).post()
…
```

```
      S E N D
+     M O R E
= M O N E Y
```

```
…
IntVar[] ALL = [
        S, E, N, D,
        M, O, R, E,
        M, O, N, E, Y]
int[] COEFFS = [
        1000, 100, 10, 1,
        1000, 100, 10, 1,
        -10000, -1000, -100, -10, -1]
model.scalar(ALL, COEFFS, "=", 0).post()

model.solver.findSolution()
```

```
Solution: S=9, E=5, N=6,
D=7, M=1, O=0, R=8, Y=2,
```

Dietary restrictions

	Bread	Milk	Cheese	Potato	Fish	Yogurt
Cost	2.0	3.5	8.0	1.5	11.0	1.0
Protein (g)	4.0	8.0	7.0	1.3	8.0	9.2
Fat (g)	1.0	5.0	9.0	0.1	7.0	1.0
Carbohydrates (g)	15.0	11.7	0.4	22.6	0.0	17.0
Calories	90	120	106	97	130	180

Minimise cost of diet given:

- Must be at least 300 calories
- Not more than 10 grams of protein
- Not less than 10 grams of carbohydrates
- Not less than 8 grams of fat
- At least 0.5 units of fish
- No more than 1 unit of milk

http://support.sas.com/documentation/cdl/en/ormpug/63352/HTML/default/viewer.htm#ormpug_lpsolver_sect018.htm

Dietary restrictions (Excel)

	Bread	Milk	Cheese	Potato	Fish	Yogurt	Total
Cost	2	3.5	8	1.5	11	1	0
Protein	4	8	7	1.3	8	9.2	0
Fat	1	5	9	0.1	7	1	0
Carbs	15	11.7	0.4	22.6	0	17	0
Calories	90	120	106	97	130	180	0

Solver Parameters

Set Objective: $O$4

To: Max Min Value Of: 0

By Changing Variable Cells:

$I$3:$N$3

Subject to the Constraints:

$J$3 <= 1
$M$3 >= 0.5
$O$5 <= 10
$O$6 >= 8
$O$7 >= 10
$O$8 >= 300

Add

Change

Delete

Reset All

Load/Save

Make Unconstrained Variables Non-Negative

Select a Solving Method: GRG Nonlinear

Options

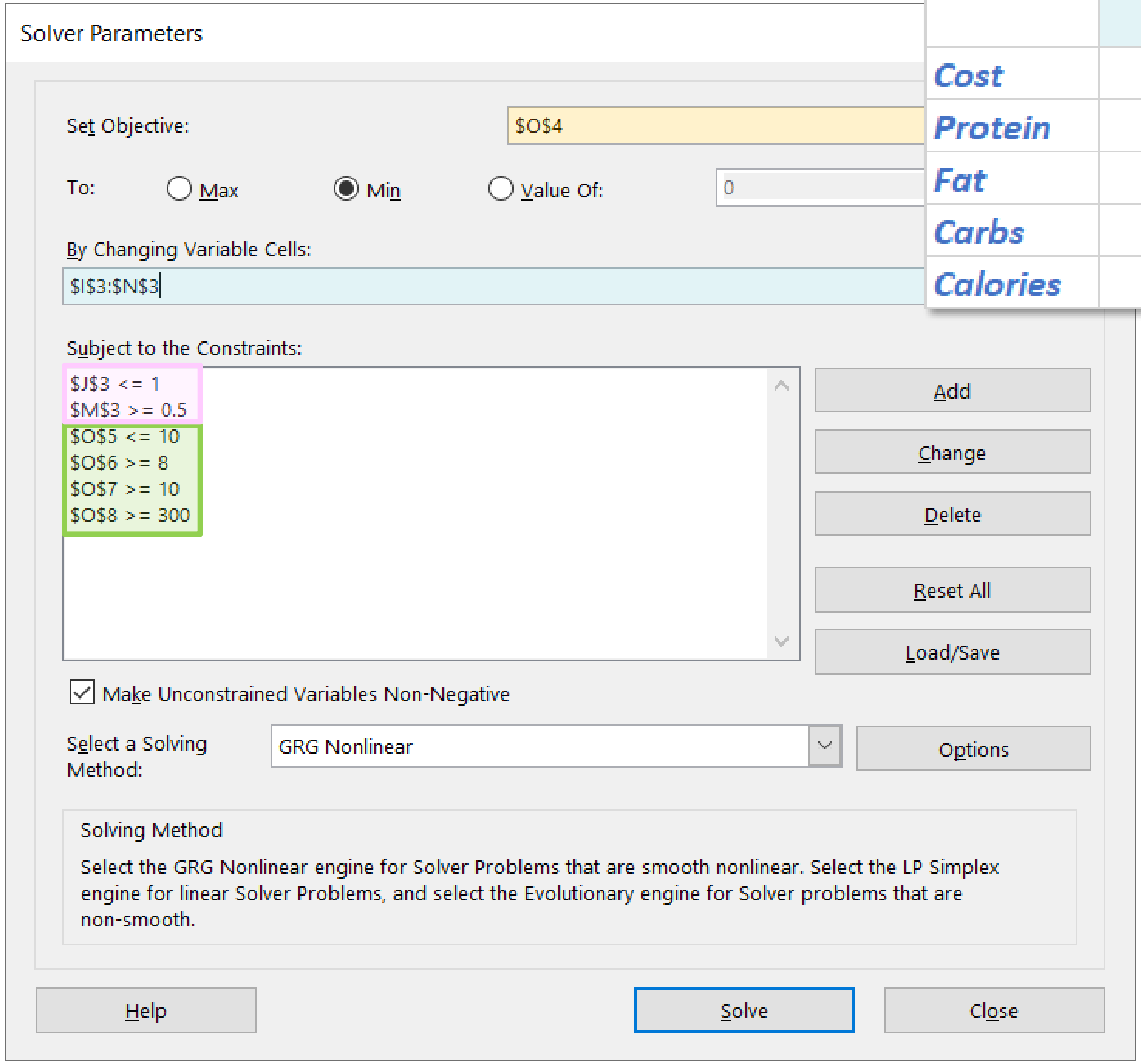
Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help Solve Close

Dietary restrictions (Excel)

	Bread	Milk	Cheese	Potato	Fish	Yogurt	Total
	0	0.053599	0.449499	1.865168	0.5	0	
Cost	2	3.5	8	1.5	11	1	12.08134
Protein	4	8	7	1.3	8	9.2	10
Fat	1	5	9	0.1	7	1	8
Carbs	15	11.7	0.4	22.6	0	17	42.9597
Calories	90	120	106	97	130	180	300



Dietary restrictions (Google sheets)

	Bread	Milk	Cheese	Potato	Fish	Yogurt	Total	Min	Max
	0.0000	0.0536	0.4495	1.8652	0.5000	0.0000			
Cost	2	3.5	8	1.5	11	1	12.08133788		
Protein	4	8	7	1.3	8	9.2	10		1
Fat	1	5	9	0.1	7	1	8	8	
Carbs	15	11.7	0.4	22.6	0	17	42.95969651	10	
Calories	90	120	106	97	130	180	300	300	
Min					0.5				
Max		1							

Objective Cell:

I4 Update Clear

Objective Sense:

- minimise
- maximise
- target value: 0

Variable Cells:

C3:H3

Add Update Delete

Unconstrained variables non-negative

Constraints:

<Add new constraint>

I5 <= K5
I6 >= J6
I7 >= J7
I8 >= J8
G3 >= G10
D3 <= D11

Diet problem (ojalgo)

```
def model = new ExpressionsBasedModel()

def bread = model.addVariable("Bread").lower(0)
def milk = model.addVariable("Milk").lower(0).upper(1)
def cheese = model.addVariable("Cheese").lower(0)
def potato = model.addVariable("Potato").lower(0)
def fish = model.addVariable("Fish").lower(0.5)
def yogurt = model.addVariable("Yogurt").lower(0)

def cost = model.addExpression("Cost")
cost.set(bread, 2.0).set(milk, 3.5).set(cheese, 8.0).set(potato, 1.5).set(fish,
11.0).set(yogurt, 1.0)

def protein = model.addExpression("Protein").upper(10)
protein.set(bread, 4.0).set(milk, 8.0).set(cheese, 7.0).set(potato,
1.3).set(fish, 8.0).set(yogurt, 9.2)

def fat = model.addExpression("Fat").lower(8)
fat.set(bread, 1.0).set(milk, 5.0).set(cheese, 9.0).set(potato, 0.1).set(fish,
7.0).set(yogurt, 1.0)

def carbs = model.addExpression("Carbohydrates").lower(10)
carbs.set(bread, 15.0).set(milk, 11.7).set(cheese, 0.4).set(potato,
22.6).set(fish, 0.0).set(yogurt, 17.0)

def calories = model.addExpression("Calories").lower(300)
calories.set(bread, 90).set(milk, 120).set(cheese, 106).set(potato, 97).set(fish,
130).set(yogurt, 180)

def result = model.minimise()

// for a variation, see:
// https://www.ojalgo.org/2019/05/the-diet-problem/
```

```
…
OPTIMAL 0.0 @ { 0.0, 0.0, 0.40813898143741034,
1.8538791051880057, 0.5916230366492151, 0.0 }
############################################
0 <= Bread: 0
0 <= Milk: 0 <= 1
0 <= Cheese: 0.408139
0 <= Potato: 1.853879
0.5 <= Fish: 0.591623
0 <= Yogurt: 0
10 <= Carbohydrates: 42.060923
8 <= Fat: 8.0
Cost: 12.553784
Protein: 10.0 <= 10
300 <= Calories: 300.0
############################################
```

Diet problem (Choco)

```
def model = new Model("Diet problem")
def unbounded = 100000

// scale quantities by 10, coefficients by 10, products by 100
def bread = model.intVar("Bread", 0, unbounded)
def milk = model.intVar("Milk", 0, 10)
def cheese = model.intVar("Cheese", 0, unbounded)
def potato = model.intVar("Potato", 0, unbounded)
def fish = model.intVar("Fish", 5, unbounded)
def yogurt = model.intVar("Yogurt", 0, unbounded)
IntVar[] all = [bread, milk, cheese, potato, fish, yogurt]

def cost = model.intVar("Cost", 0, unbounded)
model.scalar(all, [20, 35, 80, 15, 110, 10] as int[], "=", cost).post()

def protein = model.intVar("Protein", 0, 1000)
model.scalar(all, [40, 80, 70, 13, 80, 92] as int[], "=", protein).post()

def fat = model.intVar("Fat", 800, unbounded)
model.scalar(all, [10, 50, 90, 1, 70, 10] as int[], "=", fat).post()

def carbs = model.intVar("Carbohydrates", 1000, unbounded)
model.scalar(all, [150, 117, 4, 226, 0, 170] as int[], "=", carbs).post()

def calories = model.intVar("Calories", 30000, unbounded)
model.scalar(all, [900, 1200, 1060, 970, 1300, 1800] as int[], "=", calories).post()

model.setObjective(Model.MINIMIZE, cost)

def found = model.solver.findSolution()
if (found) {
    all.each { println "$it.name: ${it.value / 10}" }
    [carbs, fat, protein, calories, cost].each { println "$it.name: ${it.value / 100}" }
} else {
    println "No solution"
}
```

```
Bread: 0
Milk: 0
Cheese: 0.5
Potato: 1.9
Fish: 0.5
Yogurt: 0
Carbohydrates: 43.14
Fat: 8.19
Protein: 9.97
Calories: 302.3
Cost: 12.35
```

Choco supports RealVar but doesn't have as rich a set of possible constraints for such vars.

Diet problem (Choco)

```
def model = new Model("Diet problem")
def unbounded = 1000.0d
def precision = 0.00001d

// scale quantities by 10, coefficients by 10, products by 100
def bread = model.realVar("Bread", 0.0, unbounded, precision)
def milk = model.realVar("Milk", 0.0, 1.0, precision)
def cheese = model.realVar("Cheese", 0.0, unbounded, precision)
def potato = model.realVar("Potato", 0.0, unbounded, precision)
def fish = model.realVar("Fish", 0.5, unbounded, precision)
def yogurt = model.realVar("Yogurt", 0.0, unbounded, precision)
RealVar[] all = [bread, milk, cheese, potato, fish, yogurt]

def scalarIbex = { coeffs, var ->
    def (a, b, c, d, e, f) = coeffs
    model.realIbexGenericConstraint("$a*{0}+$b*{1}+$c*{2}+$d*{3}+$e*{4}+$f*{5}={6}",
        [*all, var] as RealVar[]).post();
}

def cost = model.realVar("Cost", 0.0, unbounded, precision)
scalarIbex([2.0, 3.5, 8.0, 1.5, 11.0, 1.0], cost)
def protein = model.realVar("Protein", 0.0, 10.0, precision)
scalarIbex([4.0, 8.0, 7.0, 1.3, 8.0, 9.2], protein)
def fat = model.realVar("Fat", 8.0, unbounded, precision)
scalarIbex([1.0, 5.0, 9.0, 0.1, 7.0, 1.0], fat)
def carbs = model.realVar("Carbohydrates", 10.0, unbounded, precision)
scalarIbex([15.0, 11.7, 0.4, 22.6, 0.0, 17.0], carbs)
def calories = model.realVar("Calories", 300, unbounded, precision)
scalarIbex([90, 120, 106, 97, 130, 180], calories)

model.setObjective(Model.MINIMIZE, cost)

def found = model.solver.findSolution()
```

```
def pretty = { var ->
    def bounds = found.getRealBounds(var)
    printf "%s: %.6f .. %.6f%n", var.name, *bounds
}

if (found) {
    all.each { pretty(it) }
    [carbs, fat, protein, calories, cost].each { pretty(it) }
} else {
    println "No solution"
}
```

```
Bread: 0.025131 .. 0.025137
Milk: 0.000009 .. 0.000010
Cheese: 0.428571 .. 0.428571
Potato: 1.848118 .. 1.848124
Fish: 0.561836 .. 0.561836
Yogurt: 0.000007 .. 0.000010
Carbohydrates: 42.316203 .. 42.316211
Fat: 8.000000 .. 8.000005
Protein: 9.997920 .. 9.997926
Calories: 300.000000 .. 300.000008
Cost: 12.431241 .. 12.431245
```

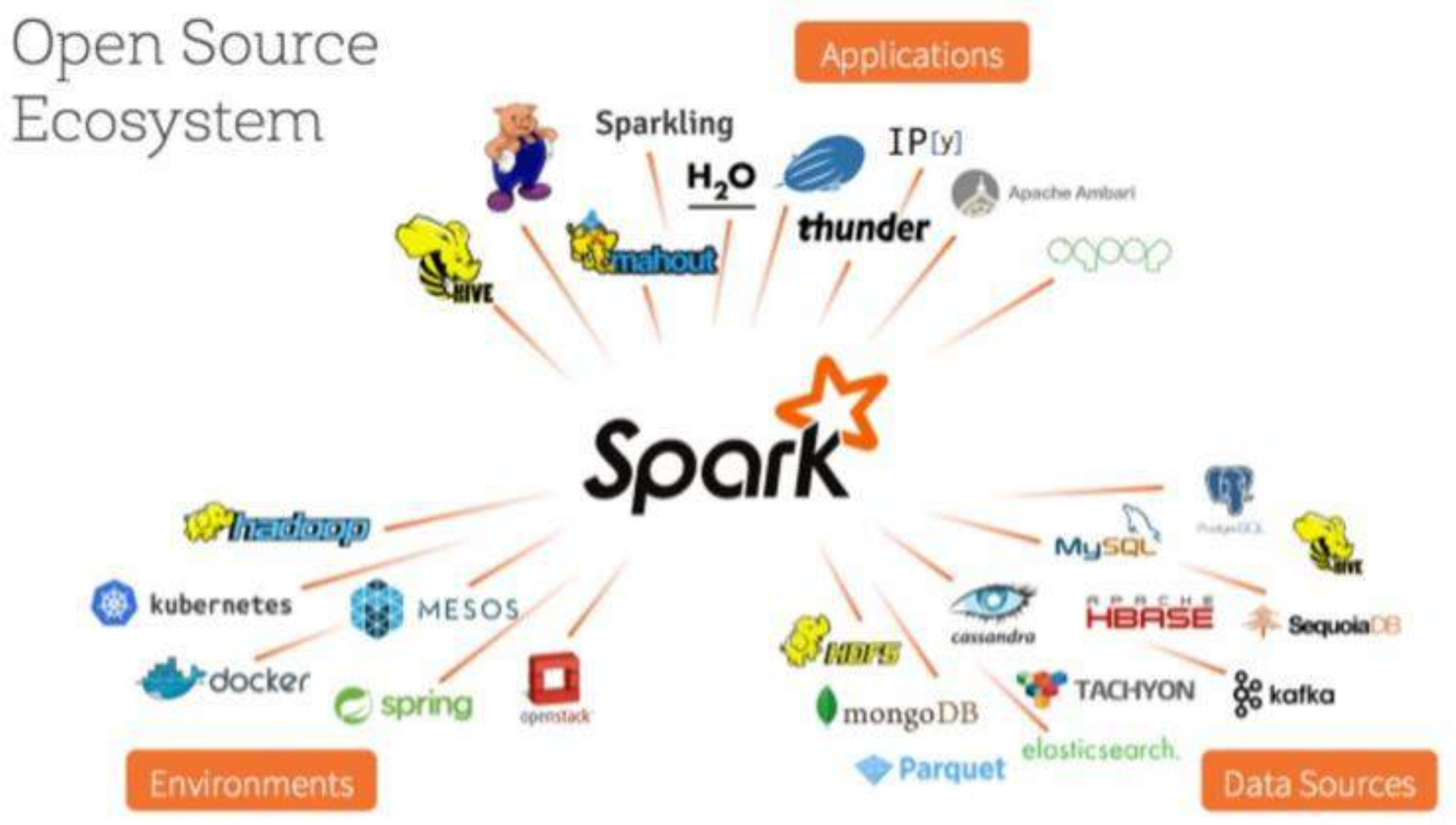
Choco does have a plugin (via JNI) for the Ibex C++ constraint processing library which does handle real numbers.

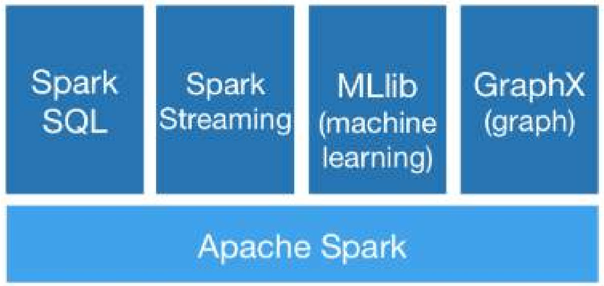
Diet problem (Apache Commons Math)

```
import org.apache.commons.math3.optim.linear.*
import org.apache.commons.math3.optim.nonlinear.scalar.GoalType
import static org.apache.commons.math3.optim.linear.Relationship.*

def cost = new LinearObjectiveFunction([2.0, 3.5, 8.0, 1.5, 11.0, 1.0] as double[], 0)

static scalar(coeffs, rel, val) { new LinearConstraint(coeffs as double[], rel, val) }

def bread_min  = scalar([1, 0, 0, 0, 0, 0], GEQ, 0)
def milk_min   = scalar([0, 1, 0, 0, 0, 0], GEQ, 0)
def milk_max   = scalar([0, 1, 0, 0, 0, 0], LEQ, 1)
def cheese_min = scalar([0, 0, 1, 0, 0, 0], GEQ, 0)
def potato_min = scalar([0, 0, 0, 1, 0, 0], GEQ, 0)
def fish_min   = scalar([0, 0, 0, 0, 1, 0], GEQ, 0.5)
def yogurt_min = scalar([0, 0, 0, 0, 0, 1], GEQ, 0)
def protein    = scalar([4.0, 8.0, 7.0, 1.3, 8.0, 9.2],     LEQ, 10)
def fat        = scalar([1.0, 5.0, 9.0, 0.1, 7.0, 1.0],     GEQ, 8)
def carbs      = scalar([15.0, 11.7, 0.4, 22.6, 0.0, 17.0], GEQ, 10)
def calories   = scalar([90, 120, 106, 97, 130, 180],       GEQ, 300)

LinearConstraintSet constraints = [bread_min, milk_min, milk_max, fish_min, cheese_min,
                                   potato_min, yogurt_min, protein, fat, carbs, calories]

def solution = new SimplexSolver().optimize(cost, constraints, GoalType.MAXIMIZE)

if (solution != null) {
    println "Opt: $solution.value"
    println solution.point.collect{ sprintf '%.2f', it }.join(', ')
}
```

```
Opt: 12.553783912422674
-0.00, -0.00, 0.41, 1.85, 0.59, 0.00
```

Apache Spark





Programming Guides:

- Quick Start: a quick introduction to the Spark API; start here!
- RDD Programming Guide: overview of Spark basics - RDDs
- Spark SQL, Datasets, and DataFrames: processing structure
- Structured Streaming: processing structured data streams wi
- Spark Streaming: processing data streams using DStreams (
- MLlib: applying machine learning algorithms
- GraphX: processing graphs

API Docs:

- Spark Scala API (Scaladoc)
- Spark Java API (Javadoc)
- Spark Python API (Sphinx)
- Spark R API (Roxygen2)
- Spark SQL, Built-in Functions (MkDocs)

Source: https://spark.apache.org/ and https://renovacloud.com/en/an-introduction-to-and-evaluation-of-apache-spark-for-big-data-architectures/

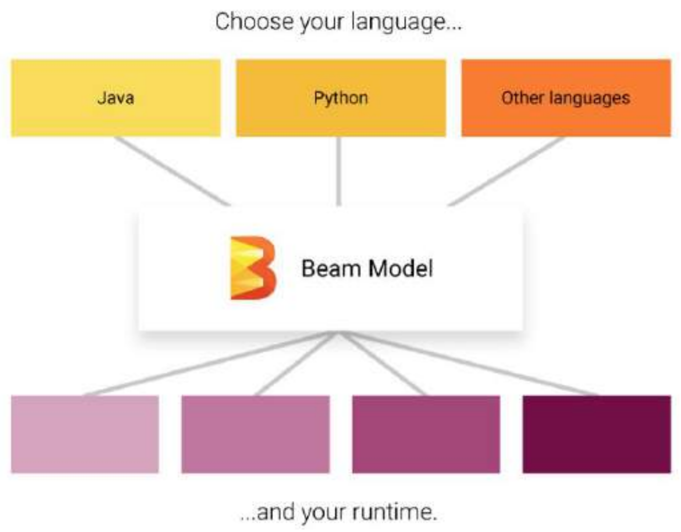
Apache Spark

```
import scala.Tuple2
import org.apache.spark.sql.SparkSession

def SPACE  = ~" "
def spark  = SparkSession.builder()
             .config("spark.master", "local")
             .appName("JavaWordCount")
             .getOrCreate()
def lines  = spark.read().textFile('/path/to/peppers.txt').javaRDD()
def words  = lines.flatMap(s -> SPACE.split(s).iterator())
def ones   = words.mapToPair(s -> new Tuple2<>(s, 1))
def counts = ones.reduceByKey{ i1, i2 -> i1 + i2 }
def output = counts.collect()
for (tuple in output) {
    println tuple._1() + ": " + tuple._2()
}
spark.stop()
```

```
peppers: 4
where's: 1
if: 1
a: 3
picked: 4
Piper: 4
of: 4
Peter: 4
peck: 4
the: 1
pickled: 4
```

Apache Beam Overview

Apache Beam is an open source, unified model for defining both batch and streaming data-parallel processing pipelines.



Apache Beam Pipeline Runners

The Beam Pipeline Runners translate the data processing pipeline you define with your Beam program into the API compatible with the distributed processing back-end of your choice. When you run your Beam program, you'll need to specify an appropriate runner for the back-end where you want to execute your pipeline.

Beam currently supports Runners that work with the following distributed processing back-ends:

- Apache Apex
- Apache Flink
- Apache Gearpump (incubating)
- Apache Samza
- Apache Spark
- Google Cloud Dataflow

Note: You can always execute your pipeline locally for testing and debugging purposes.

Apache Beam SDKs

The Beam SDKs provide a unified programming model that can represent and transform data sets of any size, whether the input is a finite data set from a batch data source, or an infinite data set from a streaming data source. The Beam SDKs use the same classes to represent both bounded and unbounded data, and the same transforms to operate on that data. You use the Beam SDK of your choice to build a program that defines your data processing pipeline.

Beam currently supports the following language-specific SDKs:

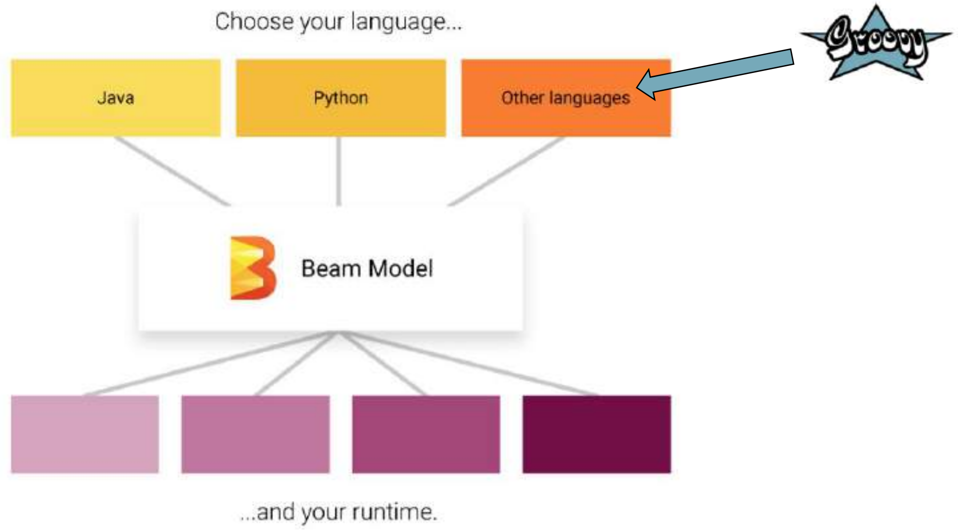
- Java
- Python
- Go

A Scala interface is also available as Scio.

Source: https://beam.apache.org/get-started/beam-overview/

Apache Beam Overview

Apache Beam is an open source, unified model for defining both batch and streaming data-parallel processing pipelines.



Apache Beam Pipeline Runners

The Beam Pipeline Runners translate the data processing pipeline you define with your Beam program into the API compatible with the distributed processing back-end of your choice. When you run your Beam program, you'll need to specify an appropriate runner for the back-end where you want to execute your pipeline.

Beam currently supports Runners that work with the following distributed processing back-ends:

- Apache Apex
- Apache Flink
- Apache Gearpump (incubating)
- Apache Samza
- Apache Spark
- Google Cloud Dataflow

Note: You can always execute your pipeline locally for testing and debugging purposes.

Apache Beam SDKs

The Beam SDKs provide a unified programming model that can represent and transform data sets of any size, whether the input is a finite data set from a batch data source, or an infinite data set from a streaming data source. The Beam SDKs use the same classes to represent both bounded and unbounded data, and the same transforms to operate on that data. You use the Beam SDK of your choice to build a program that defines your data processing pipeline.

Beam currently supports the following language-specific SDKs:

- Java
- Python
- Go

A Scala interface is also available as Scio.

Source: https://beam.apache.org/get-started/beam-overview/

Apache Beam Word Count – Quickstart guide

Apache Beam Java SDK Quickstart

Source: https://beam.apache.org/get-started/quickstart-java/

This Quickstart will walk you through executing your first Beam pipeline to run WordCount, written using Beam's Java SDK, on a runner of your choice.

Get the WordCount Code

The easiest way to get a copy of the WordCount pipeline is to use the following command to generate a simple Maven project that contains Beam's WordCount examples and builds against the most recent Beam release:

Unix PowerShell

```
PS> mvn archetype:generate `
 -D archetypeGroupId=org.apache.beam `
 -D archetypeArtifactId=beam-sdks-java-maven-archetypes-examples `
 -D archetypeVersion=2.13.0 `
 -D groupId=org.example `
 -D artifactId=word-count-beam `
 -D version="0.1" `
 -D package=org.apache.beam.examples `
 -D interactiveMode=false
```

Run WordCount

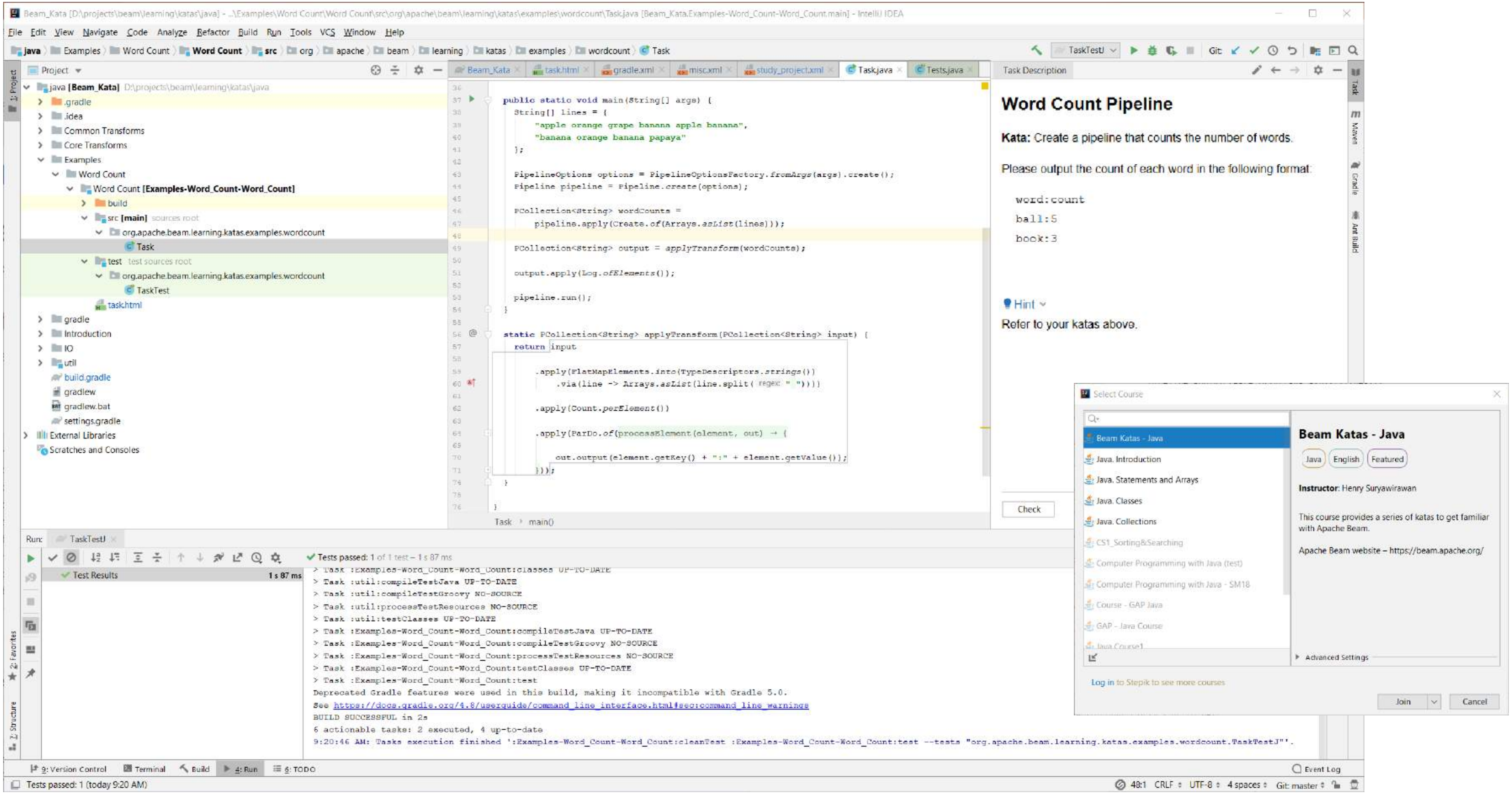
For Unix shells:

Direct Apex Flink-local Flink-cluster Spark Dataflow Samza-local Nemo Jet

```
$ mvn compile exec:java -Dexec.mainClass=org.apache.beam.examples.WordCount \
     -Dexec.args="--inputFile=pom.xml --output=counts" -Pdirect-runner
```

Apache Beam Word Count – Kata

See: https://beam.apache.org/blog/2019/05/30/beam-kata-release.html

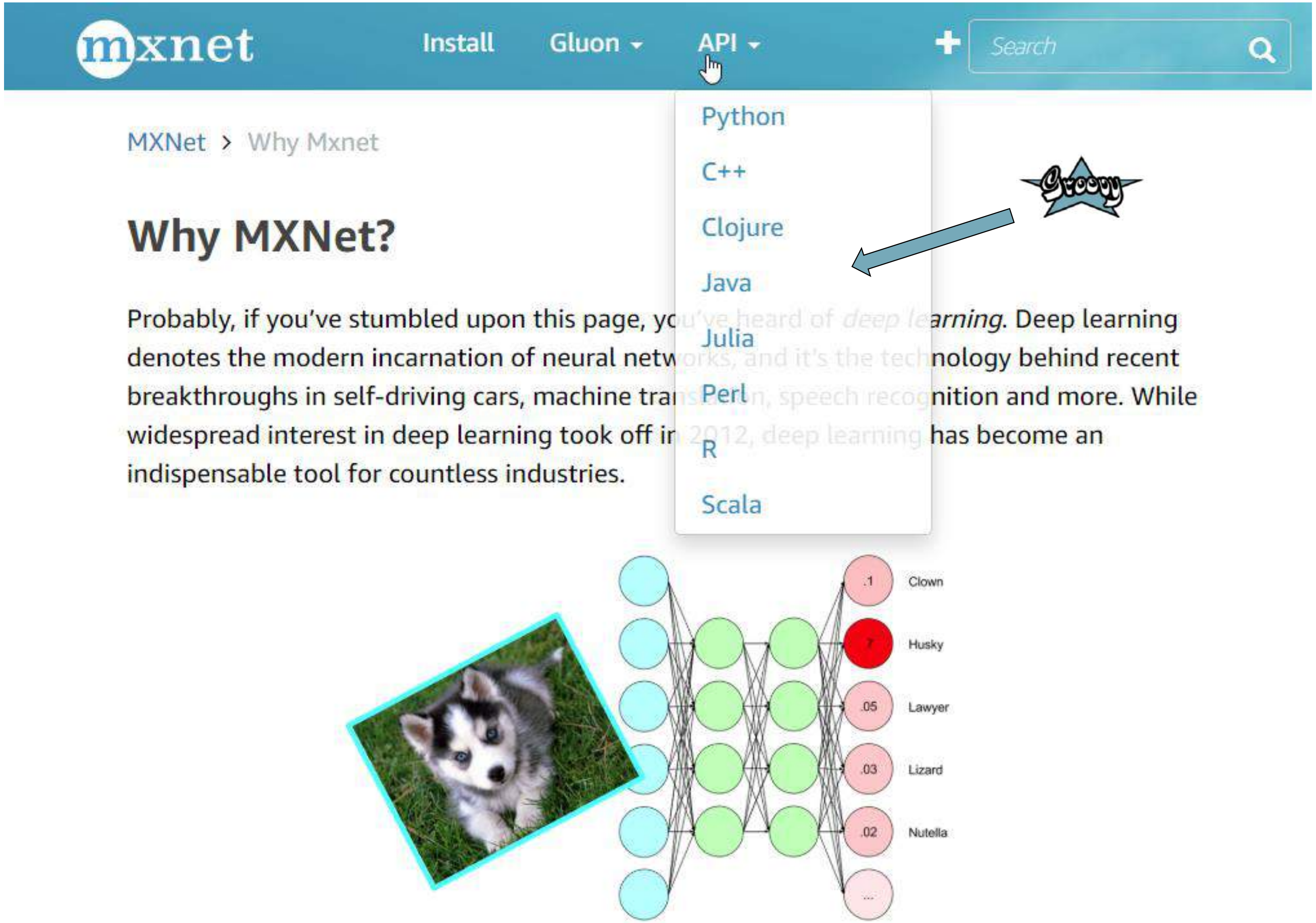


Apache Beam Word Count – GroovyConsole single file

```groovy
import …

static PCollection applyTransform(PCollection input) {
  ProcessFunction asWords = line -> line.split(" ").toList()

  def kv2out = new DoFn<KV, String>() {
    @ProcessElement
    void processElement(@Element KV element, OutputReceiver<String> out) {
      out.output(element.key + ":" + element.value)
    }
  }

  return input
    .apply(into(strings()).via(asWords))
    .apply(Count.perElement())
    .apply(ParDo.of(kv2out))
}

def lines = ["apple orange grape banana apple banana",
             "banana orange banana papaya"]

def pipeline = Pipeline.create()
def counts   = pipeline.apply(Create.of(lines))
def output   = applyTransform(counts)

output.apply(Log.ofElements())

pipeline.run()
```

```
Jun 17, 2019 11:48:16 AM org.slf4j.Logger$info$0 call
INFO: banana:4
Jun 17, 2019 11:48:16 AM org.slf4j.Logger$info$2 call
INFO: orange:2
Jun 17, 2019 11:48:16 AM org.slf4j.Logger$info call
INFO: grape:1
Jun 17, 2019 11:48:16 AM org.slf4j.Logger$info$1 call
INFO: papaya:1
Jun 17, 2019 11:48:16 AM org.slf4j.Logger$info$3 call
INFO: apple:2
```

Apache MXNET



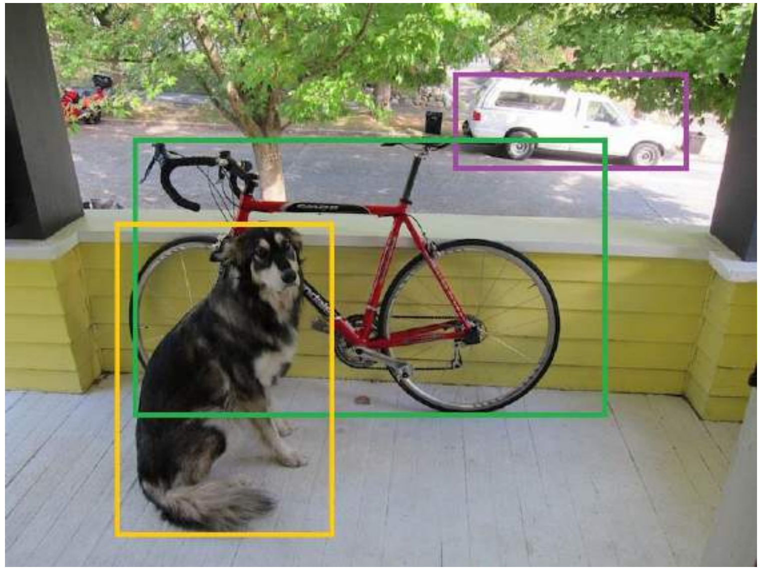
Source: https://mxnet.apache.org/versions/master/faq/why_mxnet.html

Apache MXNET Object detection

```
import org.apache.mxnet.infer.javaapi.ObjectDetector
import org.apache.mxnet.javaapi.*

static void downloadUrl(String url, String filePath) {
    def destination = filePath as File
    if (!destination.exists()) {
        destination.bytes = new URL(url).bytes
    }
}

static downloadModelImage() {
    String tempDirPath = System.getProperty('java.io.tmpdir')
    println "tempDirPath: $tempDirPath"
    def imagePath = tempDirPath + "/inputImages/resnetssd/dog-ssd.jpg"
    String imgURL = "https://s3.amazonaws.com/model-server/inputs/dog-ssd.jpg"
    downloadUrl(imgURL, imagePath)
    def modelPath = tempDirPath + "/resnetssd/resnet50_ssd_model"
    println "Download model files, this can take a while..."
    String modelURL = "https://s3.amazonaws.com/model-server/models/resnet50_ssd/"
    downloadUrl(modelURL + "resnet50_ssd_model-symbol.json",
            tempDirPath + "/resnetssd/resnet50_ssd_model-symbol.json")
    downloadUrl(modelURL + "resnet50_ssd_model-0000.params",
            tempDirPath + "/resnetssd/resnet50_ssd_model-0000.params")
    downloadUrl(modelURL + "synset.txt",
            tempDirPath + "/resnetssd/synset.txt")
    [imagePath, modelPath]
}

…
```

Apache MXNET Object detection

```
…

static detectObjects(String modelPath, String imagePath, inputShape) {
    def context = [Context.cpu()]
    def inputDescriptor = new DataDesc("data", inputShape, DType.Float32(), "NCHW")
    def objDet = new ObjectDetector(modelPath, [inputDescriptor], context, 0)
    return objDet.imageObjectDetect(ObjectDetector.loadImageFromFile(imagePath), 3)
}

def (imagePath, modelPath) = downloadModelImage()
def (width, height) = [512, 512]
Shape inputShape = new Shape([1, 3, width, height])
def results = detectObjects(modelPath, imagePath, inputShape).sum()

for (r in results) {
    print "Class: $r.className"
    printf " with probability: %.3f%n", r.probability
    def coord = [r.XMin * width, r.XMax * height, r.YMin * width, r.YMax * height]
    println "Coord: ${coord.collect { sprintf '%.2f', it }.join(', ')}\n"
}
```



Class: car with probability: 0.998
Coord: 312.21, 456.01, 72.03, 150.66

Class: bicycle with probability: 0.905
Coord: 155.96, 383.84, 149.96, 418.95

Class: dog with probability: 0.823
Coord: 83.82, 206.64, 179.14, 476.79

Groovy Community Information

- groovy.apache.org
- groovy-lang.org
- github.com/apache/groovy
- groovycommunity.com
- dev@groovy.apache.org
- users@groovy.apache.org
- @ApacheGroovy
- objectcomputing.com/training/catalog/groovy-programming/

THANK YOU

MICRONAUT

Find me on twitter
@paulk_asert

OBJECT COMPUTING

CONNECT WITH US

1+ (314) 579-0066

@objectcomputing

objectcomputing.com

References

- https://www.analyticsvidhya.com/blog/2017/02/lintroductory-guide-on-linear-programming-explained-in-simple-english/
- Computational Mixed-Integer Programming
  https://www.birs.ca/cmo-workshops/2018/18w5208/files/GleixnerAmbros.pdf
- Integer Linear Programming: Graphical Introduction
  https://www.youtube.com/watch?v=RhHhy-8sz-4
- Integer Linear Programming: Binary Constraints
  https://www.youtube.com/watch?v=-3my1TkyFiM
  https://www.youtube.com/watch?v=B3biWsBLeCw
  https://www.youtube.com/watch?v=MO8uQnIch6I
- Linear Programming: Alternate solutions, Infeasibility, Unboundedness, & Redundancy
  https://www.youtube.com/watch?v=eMA0LWsRQQ