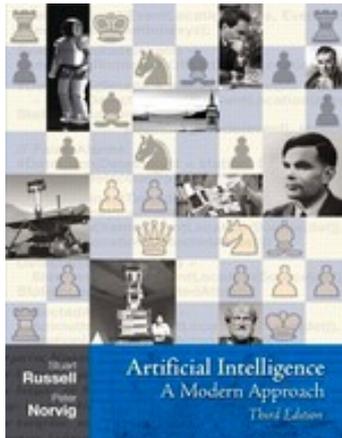


Decision Trees in AIMA, WEKA, and SCIKIT-LEARN



UCI



Machine Learning Repository

Center for Machine Learning and Intelligent Systems

Google™ Custom Search

[View ALL Data Sets](#)

Welcome to the UC Irvine Machine Learning Repository!

• Est. 1987!
• 370 data sets

We currently maintain 233 data sets as a service to the machine learning community. You may [view all data sets](#) through our searchable interface. Our old web site is still available, but is still in beta. If you wish to donate a data set, please consult our [donation policy](#). For a general overview of the Repository, please visit our [About page](#). For information about citing data sets in publications, please read our [citation policy](#). If you have any questions, feel free to [contact the Repository librarians](#). We have also set up a [mirror site](#) for the Repository.

Supported By:



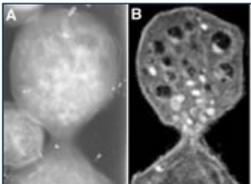
In Collaboration With:



Latest News:

- 2010-03-01: [Note](#) from donor regarding Netflix data
- 2009-10-16: Two new data sets have been added.
- 2009-09-14: Several data sets have been added.
- 2008-07-23: [Repository mirror](#) has been set up.
- 2008-03-24: New data sets have been added!
- 2007-06-25: Two new data sets have been added: UJI Pen Characters, MAGIC Gamma Telescope
- 2007-04-13: Research papers that cite the repository have been associated to specific data sets.

Featured Data Set: [Yeast](#)



Task: Classification
Data Type: Multivariate
Attributes: 8
Instances: 1484

Predicting the Cellular Localization Sites of Proteins

Newest Data Sets:

- 2012-10-21: [QtyT40I10D100K](#)
- 2012-10-19: [Legal Case Reports](#)
- 2012-09-29: [seeds](#)
- 2012-08-30: [Individual household electric power consumption](#)
- 2012-08-15: [Northix](#)
- 2012-08-06: [PAMAP2 Physical Activity Monitoring](#)
- 2012-08-04: [Restaurant & consumer data](#)
- 2012-08-03: [CNAE-9](#)

Most Popular Data Sets (hits since 2007):

- 386214: [Iris](#)
- 272233: [Adult](#)
- 237503: [Wine](#)
- 195947: [Breast Cancer Wisconsin \(Diagnostic\)](#)
- 182423: [Car Evaluation](#)
- 151635: [Abalone](#)
- 135419: [Poker Hand](#)
- 113024: [Forest Fires](#)

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[Contact](#)

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 Repository Web

Google™

Machine Learning Repository

[Center for Machine Learning and Intelligent Systems](#)

[View ALL Data Sets](#)

Zoo Data Set

Download: [Data Folder](#), [Data Set Description](#)

Abstract: Artificial, 7 classes of animals



<http://archive.ics.uci.edu/ml/datasets/Zoo>

Data Set Characteristics:	Multivariate	Number of Instances:	101	Area:	Life
Attribute Characteristics:	Categorical, Integer	Number of Attributes:	17	Date Donated	1990-05-15
Associated Tasks:	Classification	Missing Values?	No	Number of Web Hits:	18038

- 1) animal name: string
- 2) hair: Boolean
- 3) feathers: Boolean
- 4) eggs: Boolean
- 5) milk: Boolean
- 6) airborne: Boolean
- 7) aquatic: Boolean
- 8) predator: Boolean
- 9) toothed: Boolean
- 10) backbone: Boolean
- 11) breathes: Boolean
- 12) venomous: Boolean
- 13) fins: Boolean
- 14) legs: {0,2,4,5,6,8}
- 15) tail: Boolean
- 16) domestic: Boolean
- 17) catsize: Boolean
- 18) type: {mammal, fish, bird, shellfish, insect, reptile, amphibian}

Zoo training data

category
label



101 Instances

```
aardvark,1,0,0,1,0,0,1,1,1,1,0,0,4,0,0,1,mammal
antelope,1,0,0,1,0,0,0,1,1,1,0,0,4,1,0,1,mammal
bass,0,0,1,0,0,1,1,1,1,0,0,1,0,1,0,0,fish
bear,1,0,0,1,0,0,1,1,1,1,0,0,4,0,0,1,mammal
boar,1,0,0,1,0,0,1,1,1,1,0,0,4,1,0,1,mammal
buffalo,1,0,0,1,0,0,0,1,1,1,0,0,4,1,0,1,mammal
calf,1,0,0,1,0,0,0,1,1,1,0,0,4,1,1,1,mammal
carp,0,0,1,0,0,1,0,1,1,0,0,1,0,1,1,0,fish
catfish,0,0,1,0,0,1,1,1,1,0,0,1,0,1,0,0,fish
cavy,1,0,0,1,0,0,0,1,1,1,0,0,4,0,1,0,mammal
cheetah,1,0,0,1,0,0,1,1,1,1,0,0,4,1,0,1,mammal
chicken,0,1,1,0,1,0,0,0,1,1,0,0,2,1,1,0,bird
chub,0,0,1,0,0,1,1,1,1,0,0,1,0,1,0,0,fish
clam,0,0,1,0,0,0,1,0,0,0,0,0,0,0,0,0,shellfish
crab,0,0,1,0,0,1,1,0,0,0,0,0,4,0,0,0,shellfish
...
```

Zoo example

```
> aipython
```

```
>>> from learning4e import *
```

```
>>> zoo
```

```
<DataSet(zoo): 101 examples, 18 attributes>
```

```
>>> zdt = DecisionTreeLearner(zoo)
```

```
>>> zdt(['shark',0,0,1,0,0,1,1,1,1,0,0,1,0,1,0,0]) #eggs=1  
'fish'
```

```
>>> zdt(['shark',0,0,0,0,0,1,1,1,1,0,0,1,0,1,0,0]) #eggs=0  
'mammal'
```

Zoo example

>> zdt

```
DecisionTree(13, 'legs', {0: DecisionTree(12, 'fins', {0:
DecisionTree(8, 'toothed', {0: 'shellfish', 1: 'reptile'}), 1:
DecisionTree(3, 'eggs', {0: 'mammal', 1: 'fish'}})), 2:
DecisionTree(1, 'hair', {0: 'bird', 1: 'mammal'}), 4:
DecisionTree(1, 'hair', {0: DecisionTree(6, 'aquatic', {0:
'reptile', 1: DecisionTree(8, 'toothed', {0: 'shellfish', 1:
'amphibian'}})), 1: 'mammal'}), 5: 'shellfish', 6:
DecisionTree(6, 'aquatic', {0: 'insect', 1: 'shellfish'}), 8:
'shellfish'})
```

Zoo example

>>> zt.display()

Test legs

legs = 0 ==> Test fins

 fins = 0 ==> Test toothed

 toothed = 0 ==> RESULT = shellfish

 toothed = 1 ==> RESULT = reptile

 fins = 1 ==> Test eggs

 eggs = 0 ==> RESULT = mammal

 eggs = 1 ==> RESULT = fish

legs = 2 ==> Test hair

 hair = 0 ==> RESULT = bird

 hair = 1 ==> RESULT = mammal

legs = 4 ==> Test hair

 hair = 0 ==> Test aquatic

 aquatic = 0 ==> RESULT = reptile

 aquatic = 1 ==> Test toothed

 toothed = 0 ==> RESULT = shellfish

 toothed = 1 ==> RESULT = amphibian

 hair = 1 ==> RESULT = mammal

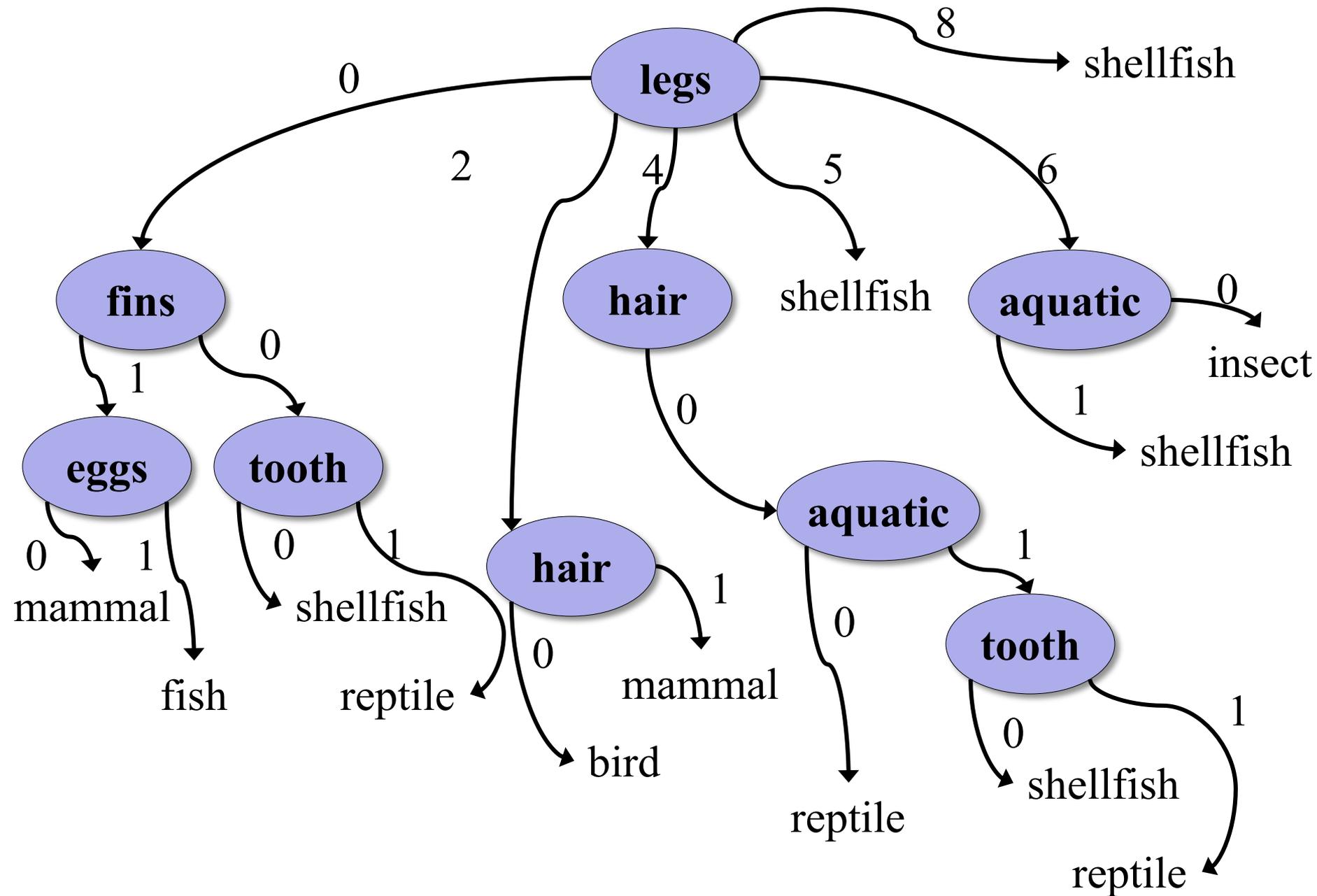
legs = 5 ==> RESULT = shellfish

legs = 6 ==> Test aquatic

 aquatic = 0 ==> RESULT = insect

 aquatic = 1 ==> RESULT = shellfish

legs = 8 ==> RESULT = shellfish



Zoo example

```
>>> dt.dt.display()
```

```
Test legs
```

```
legs = 0 ==> Test fins
```

```
  fins = 0 ==> Test toothed
```

```
    toothed = 0 ==> RESULT = shellfish
```

```
    toothed = 1 ==> RESULT = reptile
```

```
  fins = 1 ==> Test milk
```

```
    milk = 0 ==> RESULT = fish
```

```
    milk = 1 ==> RESULT = mammal
```

```
legs = 2 ==> Test hair
```

```
  hair = 0 ==> RESULT = bird
```

```
  hair = 1 ==> RESULT = mammal
```

```
legs = 4 ==> Test hair
```

```
  hair = 0 ==> Test aquatic
```

```
    aquatic = 0 ==> RESULT = reptile
```

```
    aquatic = 1 ==> Test toothed
```

```
      toothed = 0 ==> RESULT = shellfish
```

```
      toothed = 1 ==> RESULT = amphibian
```

```
  hair = 1 ==> RESULT = mammal
```

```
legs = 5 ==> RESULT = shellfish
```

```
legs = 6 ==> Test aquatic
```

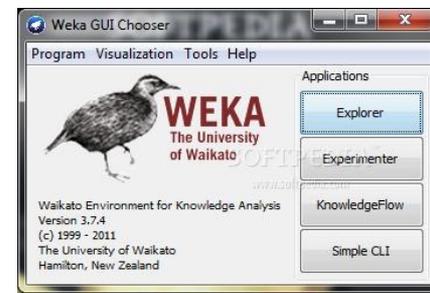
```
  aquatic = 0 ==> RESULT = insect
```

```
  aquatic = 1 ==> RESULT = shellfish
```

```
legs = 8 ==> RESULT = shellfish
```

**After adding the
shark example
to the training
data & retraining**

Weka



- Open-source Java machine learning tool
- <http://www.cs.waikato.ac.nz/ml/weka/>
- Implements many classifiers & ML algorithms
- Uses common data representation format; easy to try different ML algorithms and compare results
- Comprehensive set of data pre-processing tools and evaluation methods
- Three modes of operation: GUI, command line, Java API

Weka Explorer

Preprocess Classify Cluster Associate Select attributes Visualize

Classifier

Choose **J48 -C 1.0 -M 0**

Test options

Use training set

Supplied test set

Cross-validation Folds

Percentage split %

(Nom) WillWait

Result list (right-click for options)

20:32:20 - trees.J48
 20:32:38 - trees.J48
 20:32:40 - trees.J48
 20:33:06 - trees.J48
 20:44:28 - trees.J48

Status

OK  x 0

Weka GUI Chooser

Program Visualization Tools Help



Applications

Waikato Environment for Knowledge Analysis
 Version 3.8.0
 (c) 1999 - 2016
 The University of Waikato
 Hamilton, New Zealand

Classifier output

J48 pruned tree

```

-----
HowCrowded = None: No (2.0)
HowCrowded = Some: Yes (4.0)
HowCrowded = Full
| Hungry = Yes
| | IsFridayOrSaturday = Yes
| | | Price = $: Yes (2.0)
| | | Price = $$: Yes (0.0)
| | | Price = $$$: No (1.0)
| | IsFridayOrSaturday = No: No (1.0)
| Hungry = No: No (2.0)

Number of Leaves :    7

Size of the tree :    11

Time taken to build model: 0.11 seconds

=== Evaluation on training set ===
  
```

Common .arff* data format

% Simplified data for predicting heart disease with just six variables

% Comments begin with a % allowed at the top

@relation heart-disease-simplified *age is a numeric attribute*

@attribute age numeric

@attribute sex { female, male } *sex is a nominal attribute*

@attribute chest_pain_type { typ_angina, asympt, non_anginal, atyp_angina }

@attribute cholesterol numeric

@attribute exercise_induced_angina { no, yes }

@attribute class { present, not_present } *class is target variable*

@data

63,male,typ_angina,233,no,not_present

67,male,asympt,286,yes,present

67,male,asympt,229,yes,present

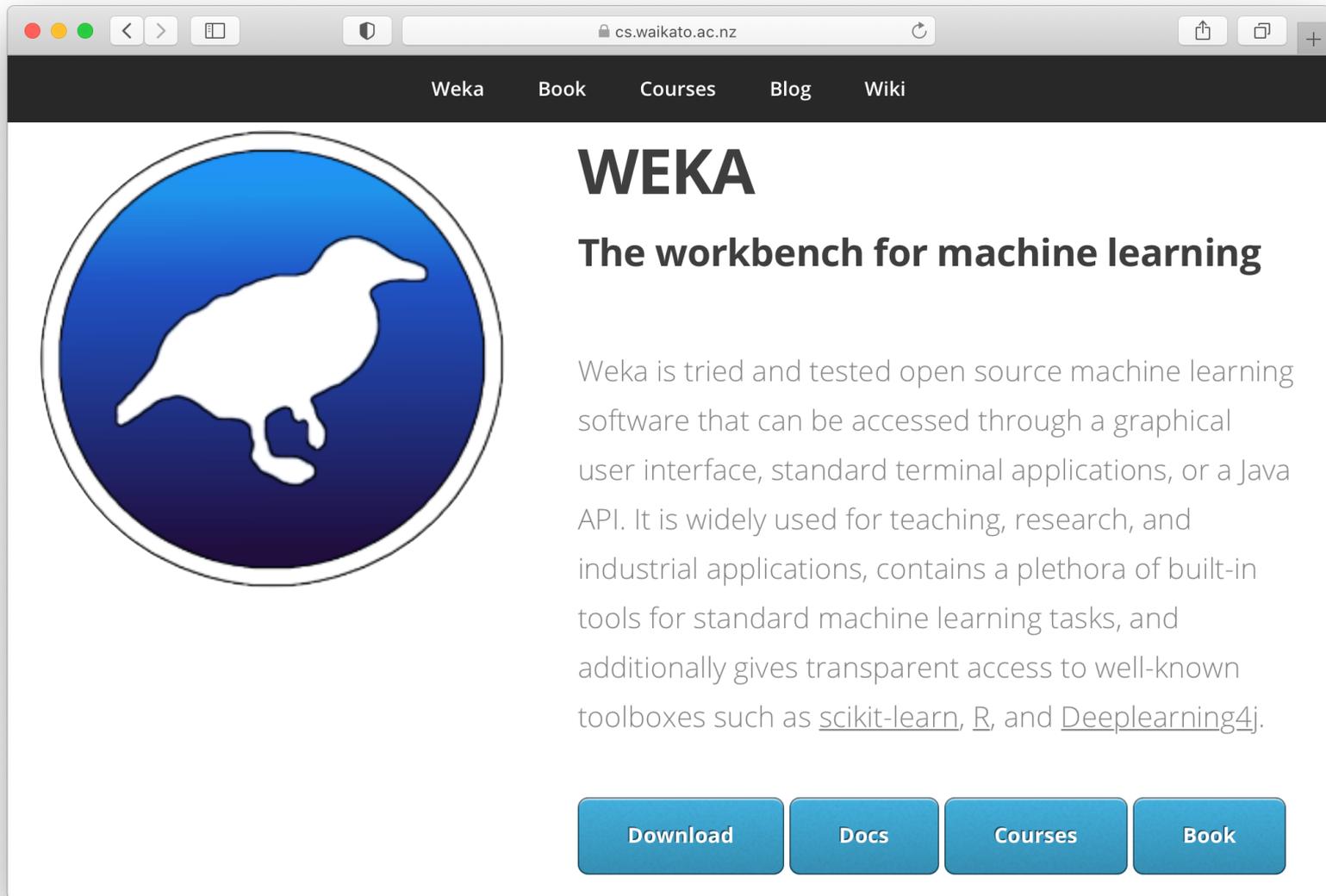
38,female,non_anginal,?,no,not_present

...

Training data

*ARFF = Attribute-Relation File Format

Weka demo

A screenshot of a web browser displaying the Weka website. The browser's address bar shows 'cs.waikato.ac.nz'. The website has a dark navigation bar with links for 'Weka', 'Book', 'Courses', 'Blog', and 'Wiki'. The main content area features a large circular logo on the left, which is a white silhouette of a kiwi bird on a blue gradient background. To the right of the logo, the word 'WEKA' is written in large, bold, black capital letters. Below it, the text 'The workbench for machine learning' is displayed in a bold, black font. A paragraph of text follows, describing Weka as open source machine learning software accessible via GUI, terminal, or Java API. At the bottom of the page, there are four blue buttons with white text: 'Download', 'Docs', 'Courses', and 'Book'.

<https://cs.waikato.ac.nz/ml/weka/>

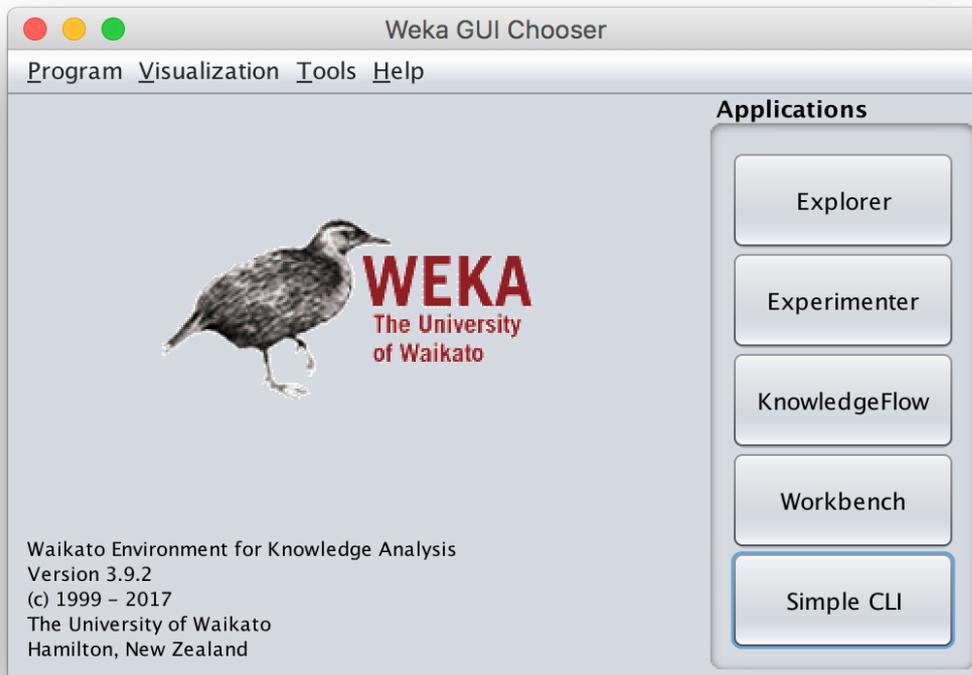
Install Weka

- Download and install [Weka](#)
- cd to your weka directory
- Invoke the GUI interface or call components from the command line
 - You may want to set environment variables (e.g., CLASSPATH) or aliases (e.g., weka)

Getting your data ready

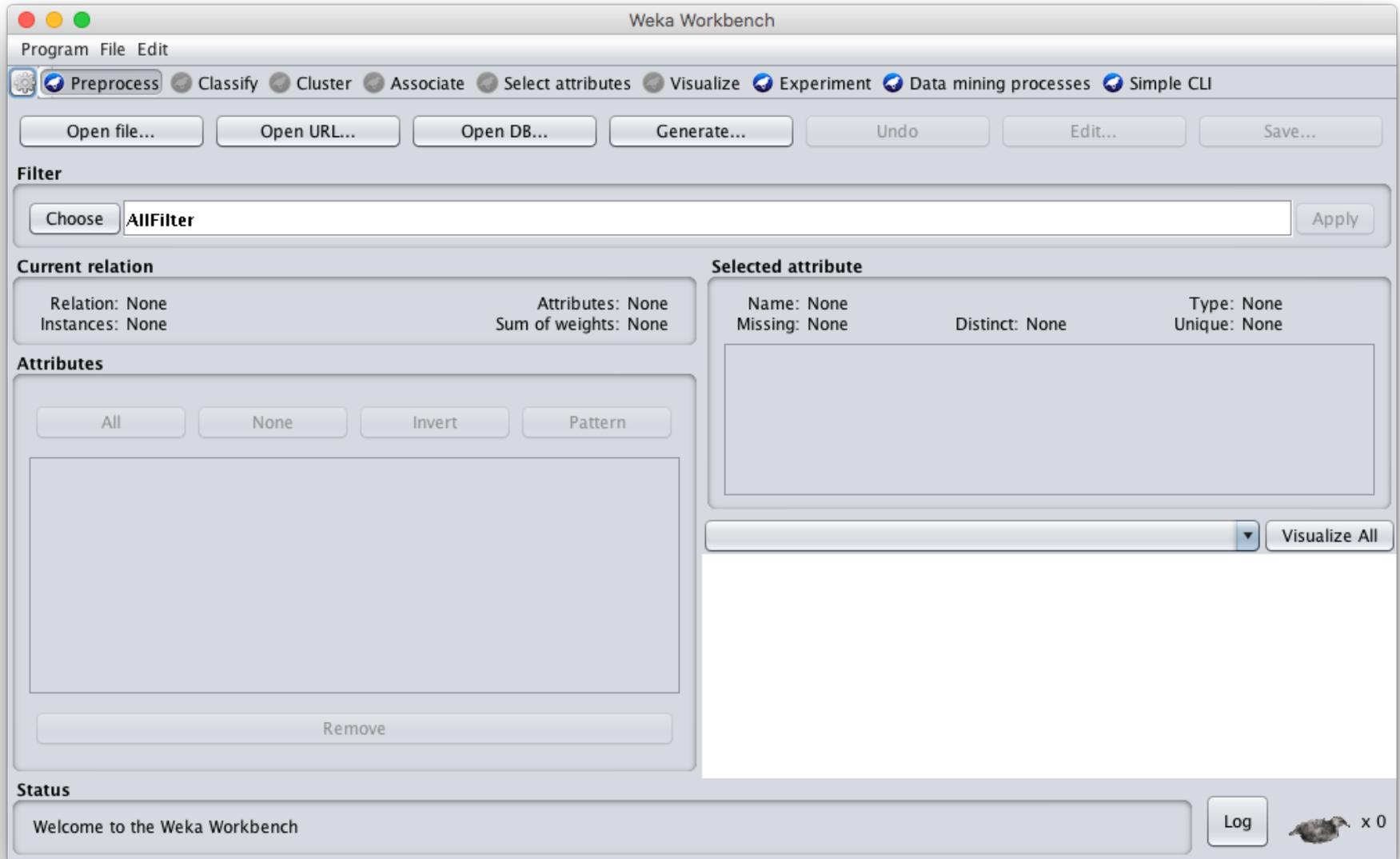
- Our class [code repo](#)'s [ML](#) directory has several data files for the restaurant example
 1. [restaurant.csv](#): original data in simple text format
 2. [restaurant.arff](#): data put in Weka's **arff** format
 3. [restaurant_test.arff](#): more data for test/evaluation
 4. [restaurant_predict.arff](#): new data we want predictions for using a saved model
- #1 is the raw training data we're given
- We'll train and save a model with #2
- Test it with #3
- Predict target on new data with #4

Open Weka app

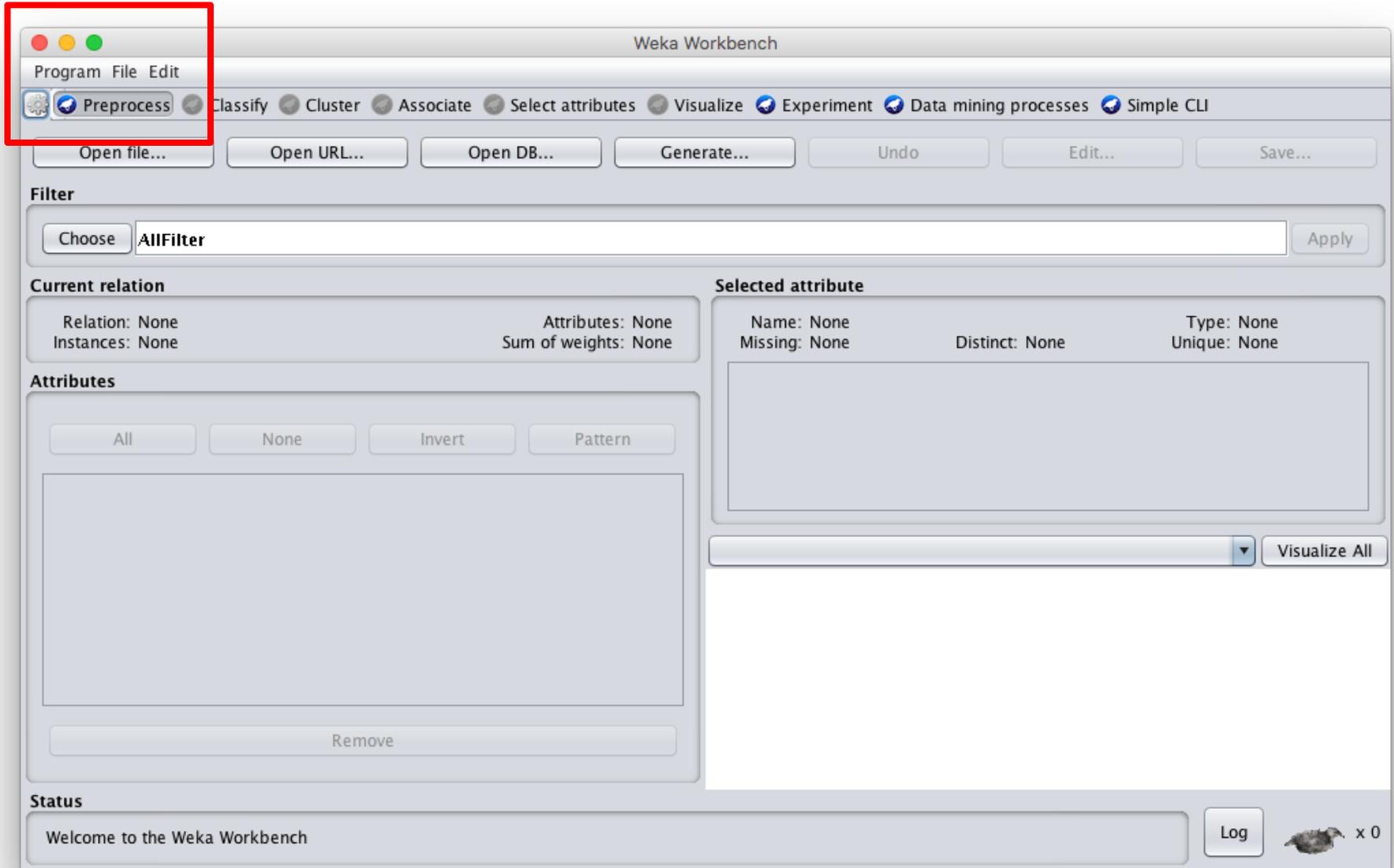


- `cd /Applications/weka`
- `java -jar weka.jar`
- Apps optimized for different tasks
- Start with Explorer

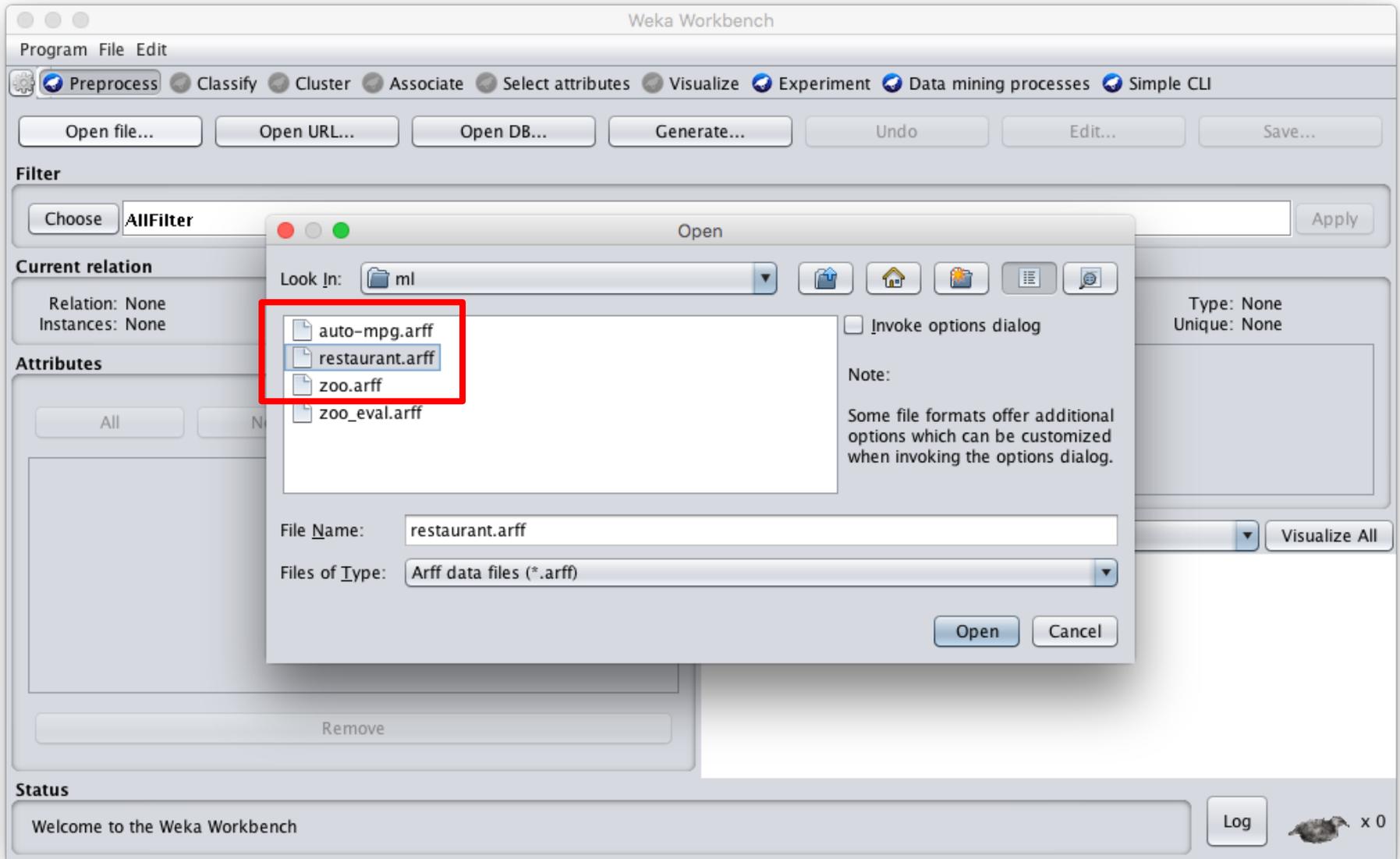
Explorer Interface



Starts with Data Preprocessing; open file to load data



Load restaurant.arff training data



We can inspect/remove features

Weka Explorer

Preprocess | Classify | Cluster | Associate | Select attributes | Visualize

Open file... | Open URL... | Open DB... | Generate... | Undo | Edit... | Save...

Filter: Choose None [Apply] [Stop]

Current relation
Relation: restaurant | Instances: 12 | Attributes: 11 | Sum of weights: 12

Attributes
[All] [None] [Invert] [Pattern]

No.	Name
1	<input checked="" type="checkbox"/> AlternateNearby
2	<input type="checkbox"/> HasBar
3	<input type="checkbox"/> IsFridayOrSaturday
4	<input type="checkbox"/> Hungry
5	<input type="checkbox"/> HowCrowded
6	<input type="checkbox"/> Price
7	<input type="checkbox"/> Raining
8	<input type="checkbox"/> Reservations
9	<input type="checkbox"/> Type
10	<input type="checkbox"/> WaitingTime
11	<input type="checkbox"/> WillWait

[Remove]

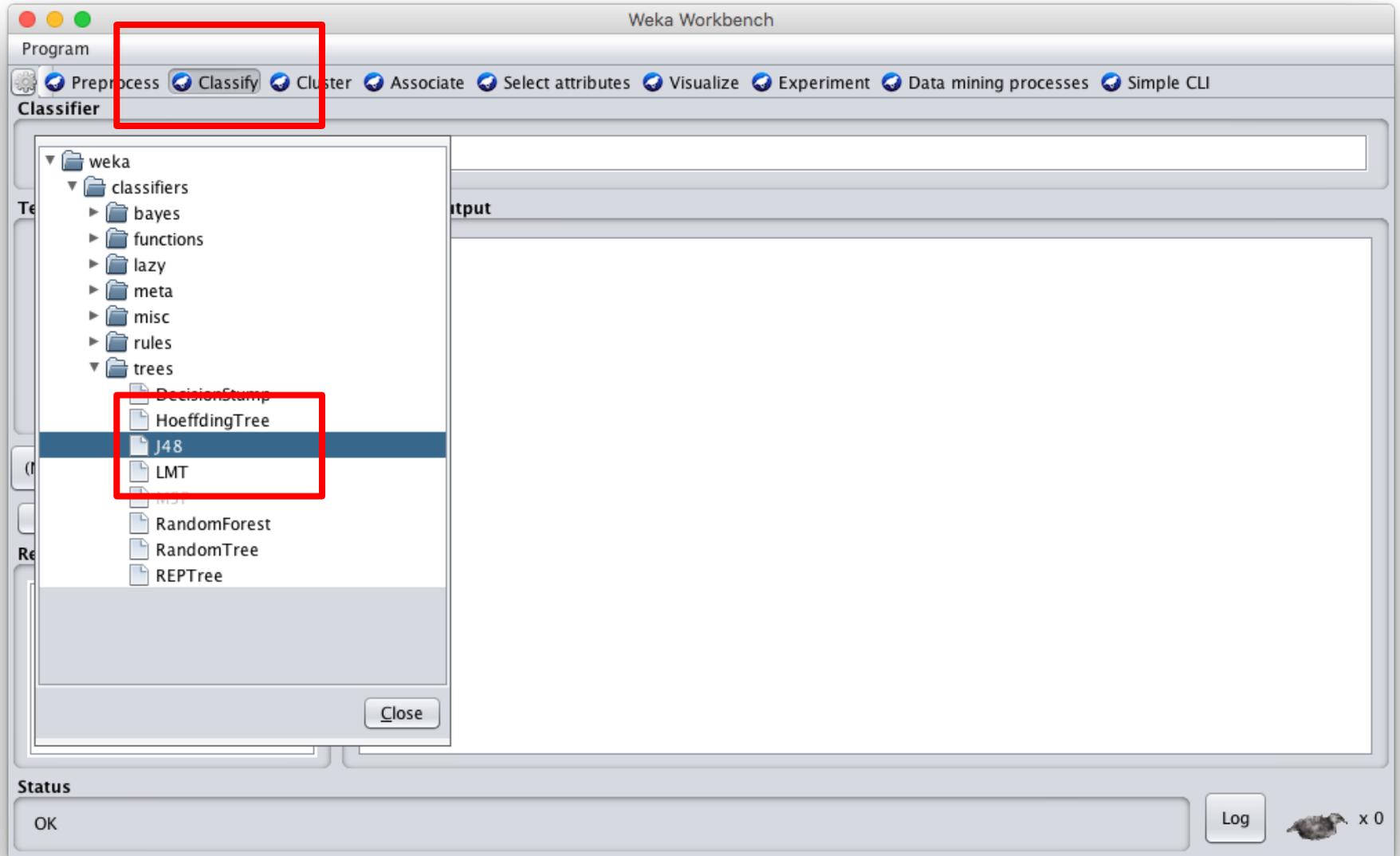
Selected attribute
Name: AlternateNearby | Type: Nominal | Missing: 0 (0%) | Distinct: 2 | Unique: 0 (0%)

No.	Label	Count	Weight
1	Yes	6	6.0
2	No	6	6.0

Class: WillWait (Nom) [Visualize All]

Status
OK [Log] x 0

Select: classify > choose > trees > J48



Adjust parameters

The image shows the Weka Workbench interface with the J48 classifier selected. The classifier command is `J48 -C 1.0 -M 1`. The 'Test options' section shows 'Cross-validation' selected with 'Folds' set to 10. The 'Classifier output' area is empty. The 'Status' bar shows 'OK'.

The 'weka.gui.GenericObjectEditor' window is open, showing the parameters for the J48 classifier. The parameters are:

- Class for generating a pruned or unpruned C4.
- batchSize: 100
- binarySplits: False
- collapseTree: True
- confidenceFactor: 0.95
- debug: False
- doNotCheckCapabilities: False
- doNotMakeSplitPointActualValue: False
- minNumObj: 1
- numDecimalPlaces: 2
- numFolds: 3
- reducedErrorPruning: False
- saveInstanceData: False
- seed: 1
- subtreeRaising: True
- unpruned: False
- useLaplace: False
- useMDLcorrection: True

Red boxes highlight the classifier command, the 'confidenceFactor' parameter, and the 'minNumObj' parameter.

Select the testing procedure

The screenshot shows the Weka Explorer interface with several windows open. The main window displays the Classifier tab with the following settings:

- Classifier: Choose J48 -C 0.95 -M 1
- Test options: Supplied test set (highlighted with a red box)
- More options... button
- Start and Stop buttons
- Result list (right-click for options):
 - 21:08:25 - trees.J48
 - 21:41:48 - trees.J48
 - 21:42:41 - trees.J48
 - 21:43:26 - trees.J48 (highlighted)
- Status: OK

The Classifier output window shows the following text:

```
Size of the tree :      11

Time taken to build model: 0.04 seconds

=== Evaluation on test set ===

Time taken to test model on supplied test set: 0

=== Summary ===

Correctly Classified Instances      3
Incorrectly Classified Instances    0
Kappa statistic                     1
Mean absolute error                 0
Root mean squared error             0
Relative absolute error             0
Root relative squared error         0
Total Number of Instances          3

=== Detailed Accuracy By Class ===

                TP Rate  FP Rate  Precision  Re
Weighted Avg.   1.000   0.000   1.000     1.

=== Confusion Matrix ===

 a b  <-- classified as
 1 0 | a = Yes
 0 2 | b = No
```

The Test Instances dialog box shows:

- Relation: restaurant
- Instances: ?
- Attributes: 11
- Sum of weights: ?
- Buttons: Open file... (highlighted with a red box), Open URL...

The Open dialog box shows the file selection process:

- Look In: ML
- Files: adult.arff, auto-mpg-test.arff, auto-mpg.arff, f196.arff, iris.arff, restaurant.arff, restaurant_predict.arff, restaurant_test.arff (highlighted with a red box), zoo.arff, zoo_eval.arff
- File Name: restaurant_test.arff
- Files of Type: Arff data files (*.arff)
- Buttons: Open, Cancel

See training results

Weka Explorer

Preprocess Classify Cluster Associate Select attributes Visualize

Classifier

Choose J48 -C 0.95 -M 1

Test options

Use training set
 Supplied test set
 Cross-validation Folds 10
 Percentage split % 66

(Nom) WillWait

Result list (right-click for options)

21:55:50 - trees.J48

Classifier output

```
HowCrowded = None: No (2.0)
HowCrowded = Some: Yes (4.0)
HowCrowded = Full
| Hungry = Yes
| | IsFridayOrSaturday = Yes
| | | Price = $: Yes (2.0)
| | | Price = $$: Yes (0.0)
| | | Price = $$$: No (1.0)
| | IsFridayOrSaturday = No: No (1.0)
| Hungry = No: No (2.0)
```

Number of Leaves : 7
Size of the tree : 11
Time taken to build model: 0.03 seconds
=== Evaluation on test set ===
Time taken to test model on supplied test set: 0 seconds

Summary

Correctly Classified Instances	3	100	%
Incorrectly Classified Instances	0	0	%
Kappa statistic	1		
Mean absolute error	0		
Root mean squared error	0		
Relative absolute error	0	%	
Root relative squared error	0	%	
Total Number of Instances	3		

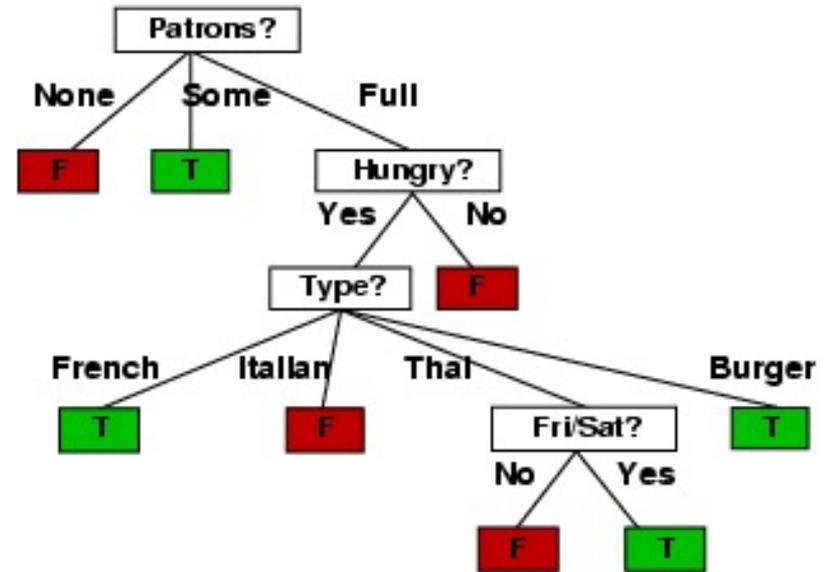
=== Detailed Accuracy By Class ===

Status

OK x 0

Compare results

HowCrowded = None: No (2.0)
HowCrowded = Some: Yes (4.0)
HowCrowded = Full
| Hungry = Yes
| | IsFridayOrSaturday = Yes
| | | Price = \$: Yes (2.0)
| | | Price = \$\$: Yes (0.0)
| | | Price = \$\$\$: No (1.0)
| | IsFridayOrSaturday = No: No (1.0)
| Hungry = No: No (2.0)



**J48 pruned tree: nodes:11;
leaves:7, max depth:4**

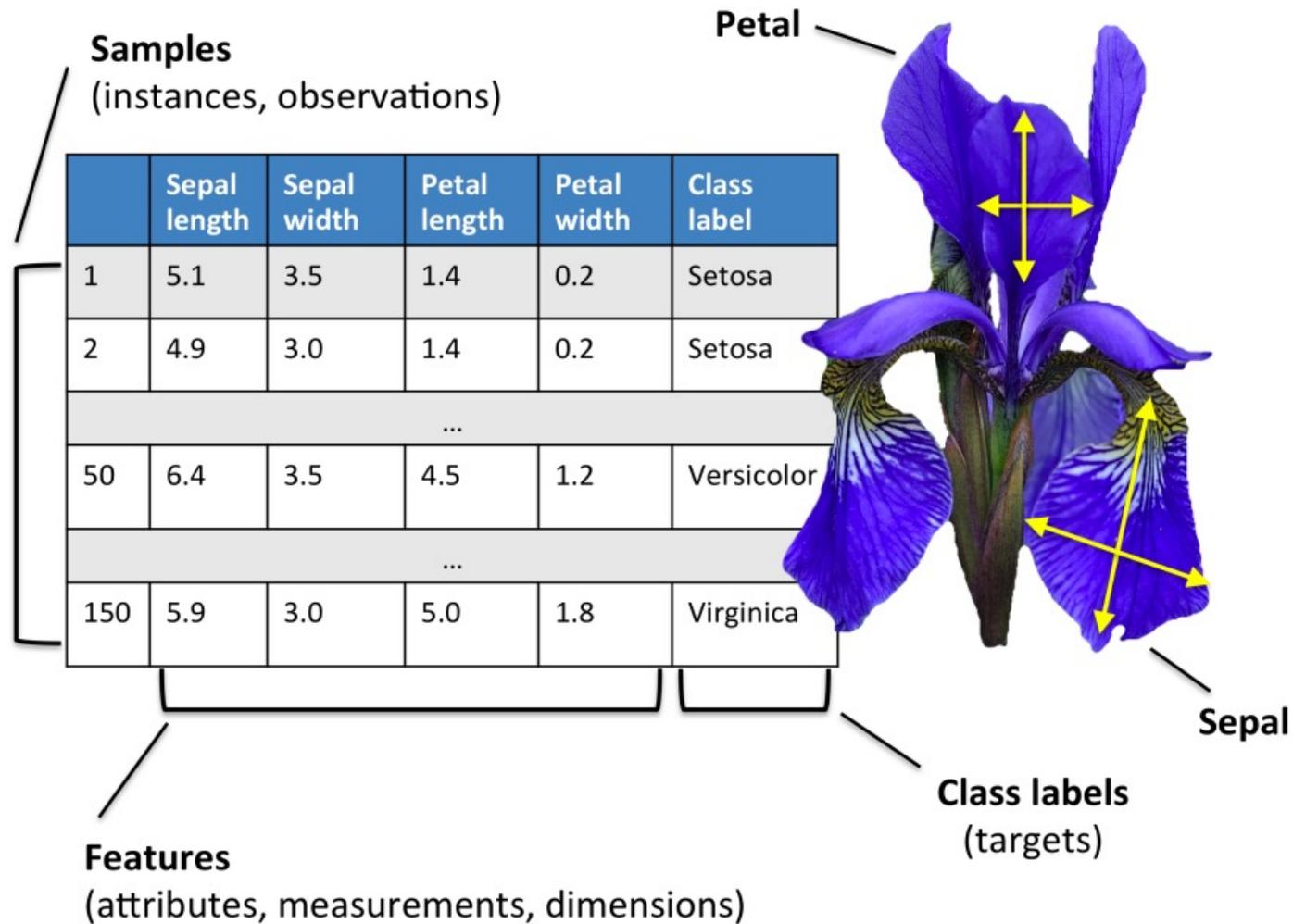
**ID3 tree: nodes:12; leaves:8,
max depth:4**

The two decision trees are equally good

scikit-learn

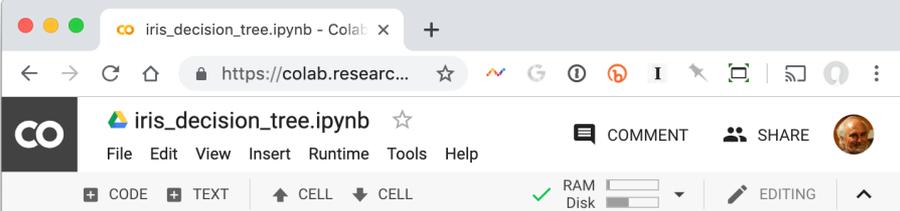


- Popular open source ML and data analysis tools for Python
- Built on [NumPy](#), [SciPy](#), and [matplotlib](#) for efficiency
- However decision tree tools are a weak area
 - E.g., data features must be numeric, so working with restaurant example requires conversion
 - Perhaps because DTs not used for large problems
- We'll look at using it to learn a DT for the classic [iris flower dataset](#)

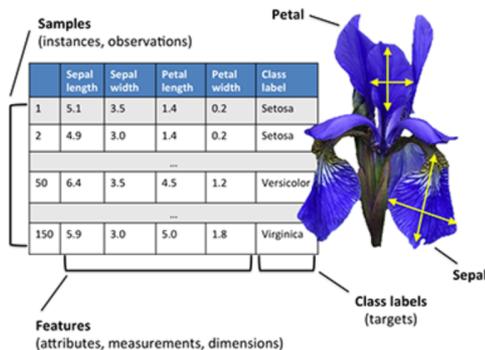


50 samples from each of three species of Iris (setosa, virginica, versicolor) with four data features: length and width of the sepals and petals in centimeters

Scikit DT



Decision tree example using the classic IRIS [data set](#), which has 50 samples from each of three species of Iris (setosa, virginica, versicolor). Four features were measured from each sample: the length and width of the sepals and petals in centimeters.



Double-click (or enter) to edit

```
[1] from sklearn import tree
from sklearn.datasets import load_iris
import graphviz
```

The `load_iris()` function returns a scikit bunch object, which has a data and target for our iris dataset

The iris data is an 150x4 array and the iris target is a vector of 150 values

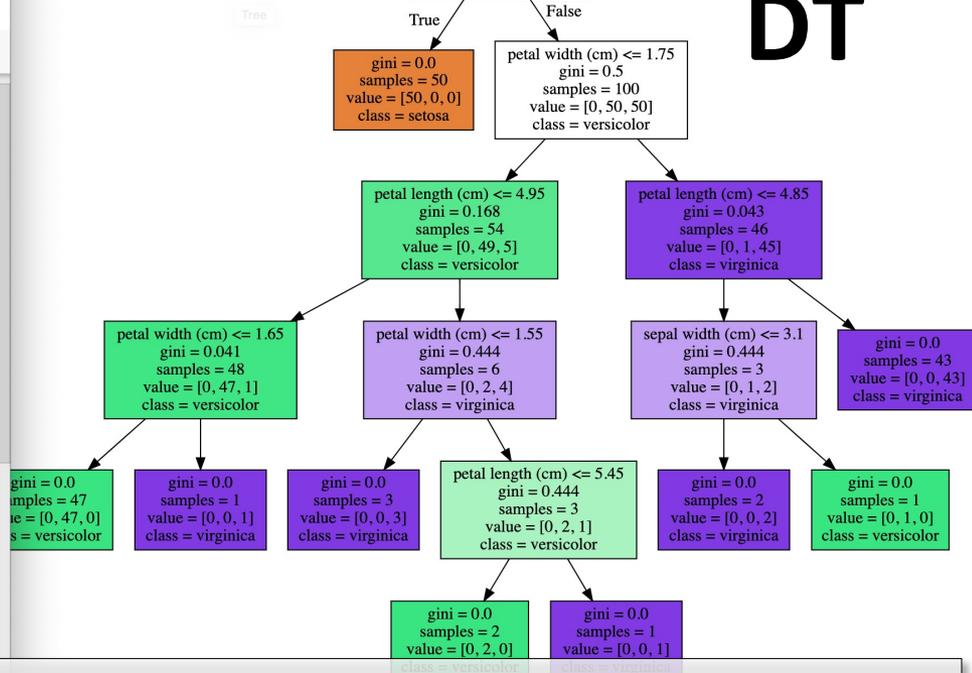
```
[2] iris = load_iris()
print('data:', iris.data.shape, 'target', iris.target.shape)
```

```
↳ data: (150, 4) target (150,)
```

Use scikit's `DecisionTreeClassifier` and use the `fit()` method to build a decision tree classifier the data and target

```
[3] clf = tree.DecisionTreeClassifier()
clf = clf.fit(iris.data, iris.target)
```

We can visualize the decision tree using the `Graphviz` open source graph visualization



```
from sklearn import tree, datasets
import graphviz, pickle

iris = datasets.load_iris()

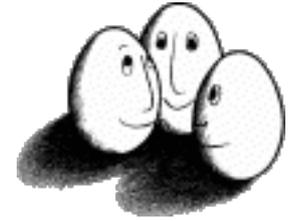
clf = tree.DecisionTreeClassifier()
clf = clf.fit(iris.data, iris.target)

pickle.dump(clf, open('iris.p', 'wb'))

tree.export_graphviz(clf, out_file="iris.pdf")
```

<http://bit.ly/iris671>

Weka vs. scikit-learn vs. ...



- Weka: good for experimenting with many ML algorithms
 - Other tools are more efficient & scalable
- [Scikit-learn](#): popular and efficient suite of open-source machine-learning tools in Python
 - Uses NumPy, SciPy, matplotlib for efficiency
 - Preloaded into Google's [Colaboratory](#)
- Custom apps for a specific ML algorithm are often preferred for speed or features