

Cheat Sheets for AI

Neural Networks,
Machine Learning,
DeepLearning &
Big Data

**The Most Complete List
of Best AI Cheat Sheets**

BecomingHuman.AI

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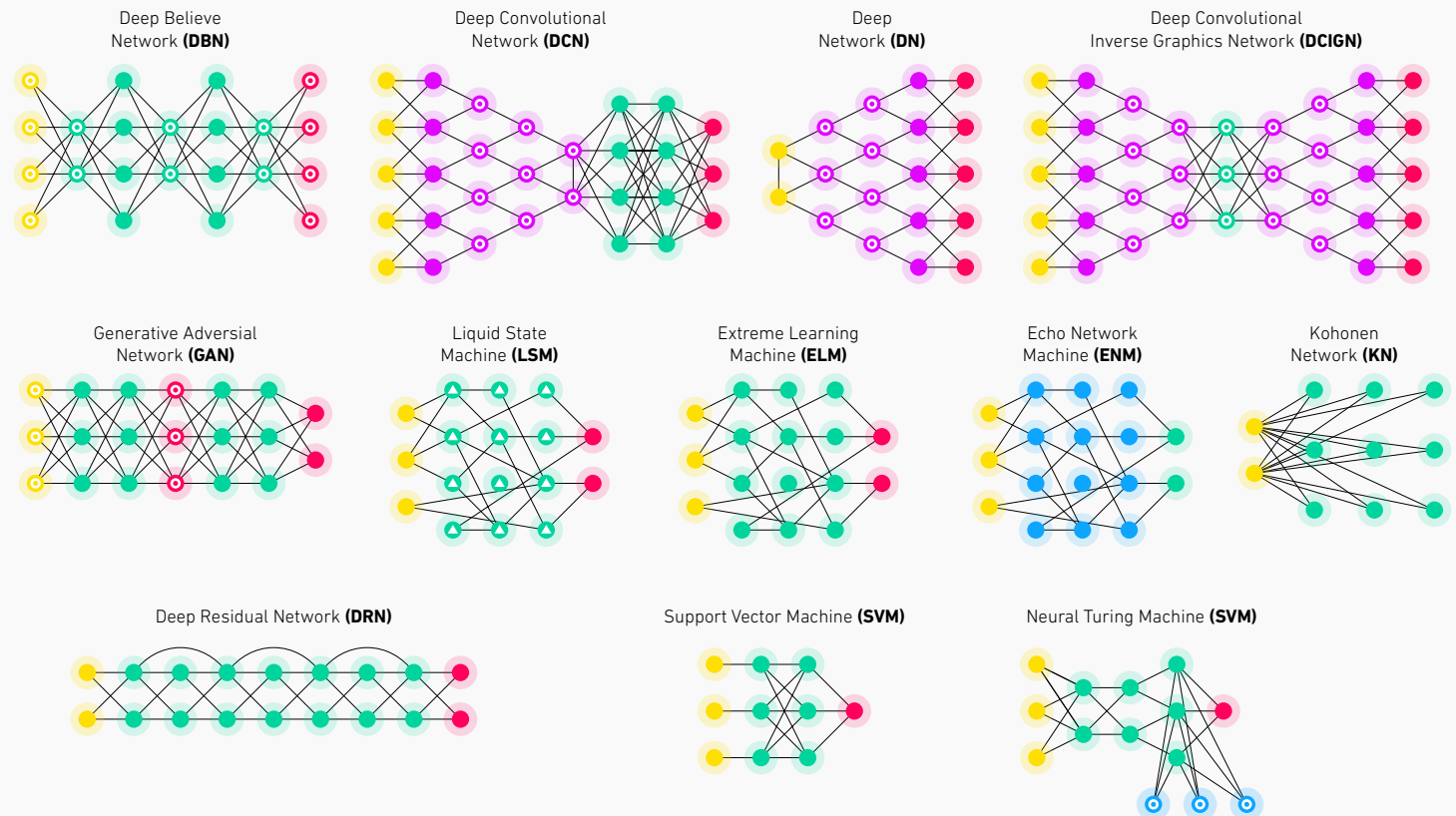
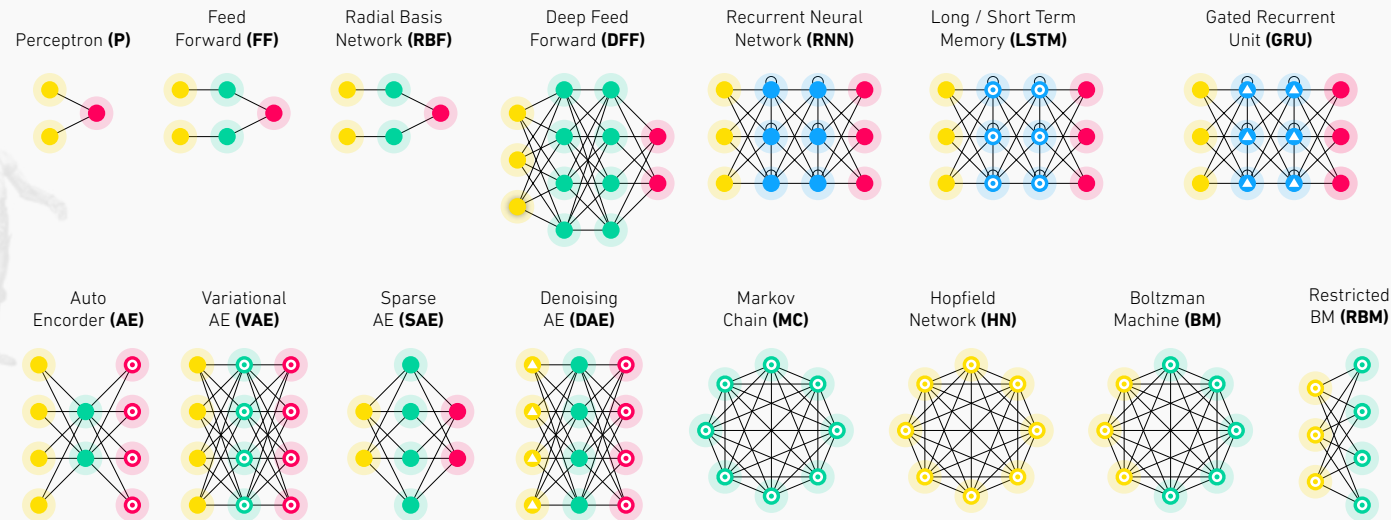
Part 1 Neural Networks

Neural Networks Basic Cheat Sheet

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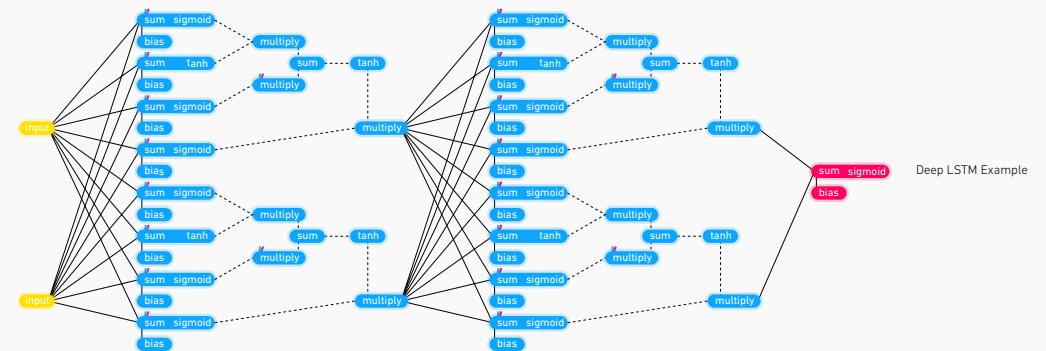
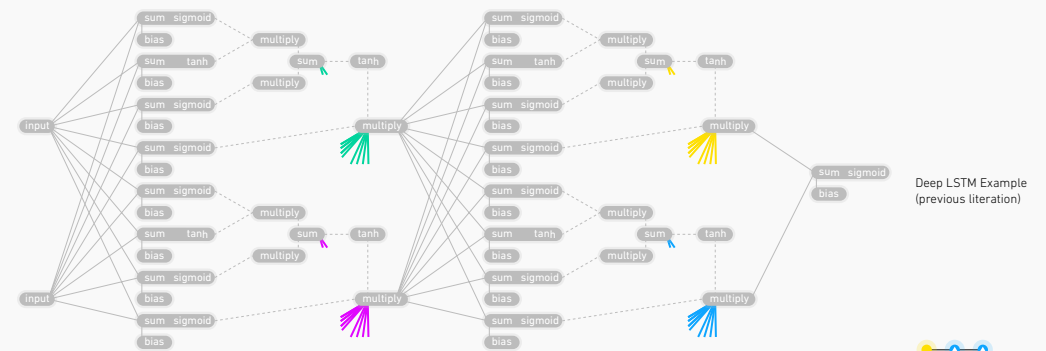
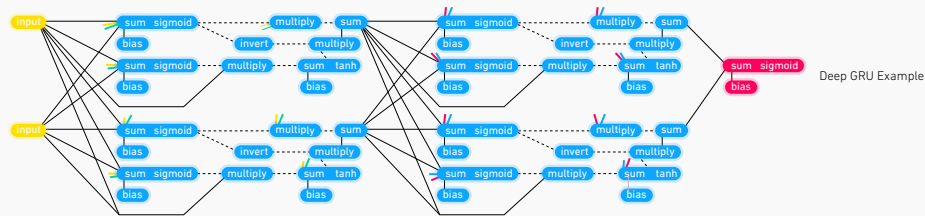
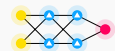
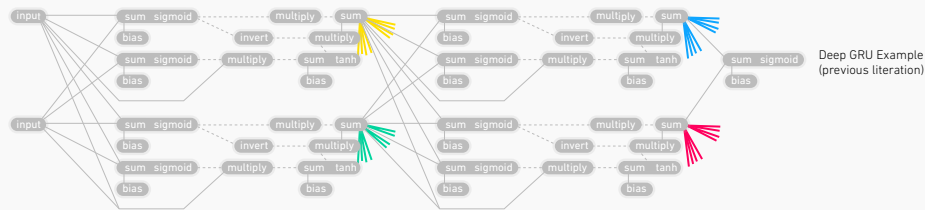
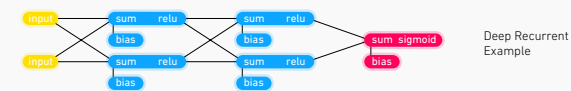
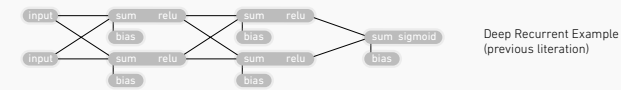
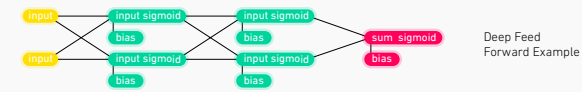
-  Backfed Input Cell
-  Input Cell
-  Noisy Input Cell
-  Hidden Cell
-  Probablistic Hidden Cell
-  Spiking Hidden Cell
-  Output Cell
-  Match Input Output Cell
-  Recurrent Cell
-  Memory Cell
-  Different Memory Cell
-  Kernel
-  Convolutional or Pool

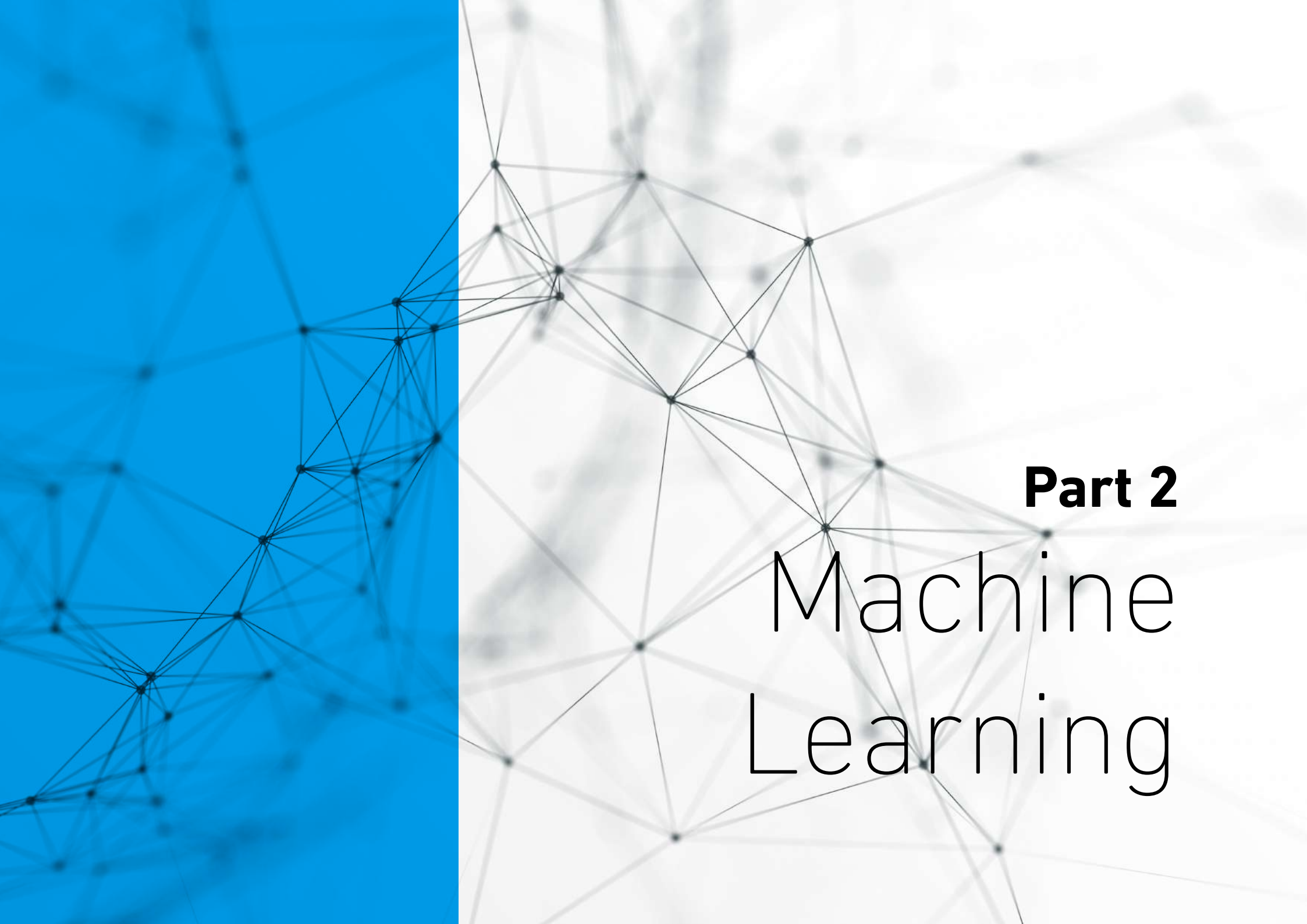


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Neural Networks Graphs Cheat Sheet

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Part 2 Machine Learning

Machine Learning Overview

MACHINE LEARNING IN EMOJI

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SUPERVISED

human builds model based on input / output

UNSUPERVISED

human input, machine output
human utilizes if satisfactory

REINFORCEMENT

human input, machine output
human reward/punish, cycle continues

BASIC REGRESSION

LINEAR

`linear_model.LinearRegression()`

Lots of numerical data



LOGISTIC

`linear_model.LogisticRegression()`

Target variable is categorical



CLUSTER ANALYSIS

K-MEANS

`cluster.KMeans()`

Similar datum into groups based on centroids



ANOMALY DETECTION

`covariance.EllipticalEnvelope()`

Finding outliers through grouping



CLASSIFICATION

NEURAL NET

`neural_network.MLPClassifier()`

Complex relationships. Prone to overfitting
Basically magic.



K-NN

`neighbors.KNeighborsClassifier()`

Group membership based on proximity



DECISION TREE

`tree.DecisionTreeClassifier()`

If/then/else. Non-contiguous data.
Can also be regression.



RANDOM FOREST

`ensemble.RandomForestClassifier()`

Find best split randomly
Can also be regression



SVM

`svm.SVC()` `svm.LinearSVC()`

Maximum margin classifier. Fundamental Data Science algorithm



NAIVE BAYES

`GaussianNB()` `MultinomialNB()` `BernoulliNB()`

Updating knowledge step by step with new info



FEATURE REDUCTION

T-DISTRI B STOCHASTIC NEIB EMBEDDING

`manifold.TSNE()`

Visual high dimensional data. Convert similarity to joint probabilities



PRINCIPLE COMPONENT ANALYSIS

`decomposition.PCA()`

Distill feature space into components that describe greatest variance



CANONICAL CORRELATION ANALYSIS

`decomposition.CCA()`

Making sense of cross-correlation matrices



LINEAR DISCRIMINANT ANALYSIS

`lda.LDA()`

Linear combination of features that separates classes



OTHER IMPORTANT CONCEPTS

BIAS VARIANCE TRADEOFF

UNDERFITTING / OVERFITTING

INERTIA

ACCURACY FUNCTION

$(TP+TN) / (P+N)$

PRECISION FUNCTION

`manifold.TSNE()`

SPECIFICITY FUNCTION

$TN / (FP+TN)$

SENSITIVITY FUNCTION

$TP / (TP+FN)$

Cheat-Sheet Skicit learn Phyton For Data Science BecomingHuman.AI



Skicit Learn

Skicit Learn is an open source Phyton library that implements a range if machine learning, processing, cross validation and visualization algorithm using a unified

A basic Example

```
>>> from sklearn import neighbors, datasets, preprocessing
>>> from sklearn.cross_validation import train_test_split
>>> from sklearn.metrics import accuracy_score
>>> iris = datasets.load_iris() >>> X, y = iris.data[:, :2], iris.target
>>> Xtrain, X test, y_train, y test = train_test_split (X, y, random stat33)
>>> scaler = preprocessing.StandardScaler().fit(X_train)
>>> X test = scaler.transform(X test)
>>> knn = neighbors.KNeighborsClassifier(n_neighbors=5)
>>> knn.fit(X_train, y_train)
>>> y_pred = knn.predict(X_test)
>>> accuracy_score(y_test, y_pred)
```

Prediction

Supervised Estimators

```
>>> y_pred = svc.predict(random.random((2,5)))
>>> y_pred = lr.predict(X_test)
>>> y_pred = knn.predict_proba(X_test)
```

Predict Labels
Predict Labels
Estimate probability of a label

Unsupervised Estimators

```
>>> y_pred = k_means.predict(X_test)
```

Predict labels in clustering algo

Loading the Data

Your data beeds to be nmueric and stored as NumPy arrays or SciPy sparse matric. other types that they are convertible to numeric arrays, such as Pandas Dataframe, are also acceptable

```
>>> import numpy as np >> X = np.random.random((10,5))
>>> y = np.array ( 'PH', 'IM', 'F', 'F', 'M', 'F', 'NI', 'tvl', 'F', 'F', 'F' )
>>> X [X < 0.7] = 0
```

Preprocessing The Data

Standardization

```
>>> from sklearn.preprocessing import StandardScaler
>>> scaler = StandardScaler().fit(X_train)
>>> standardized_X = scaler.transform(X_train)
>>> standardized_X_test = scaler.transform(X_test)
```

Normalization

```
>>> from sklearn.preprocessing import Normalizer
>>> scaler = Normalizer().fit(X_train)
>>> normalized_X = scaler.transform(X_train)
>>> normalized_X_test = scaler.transform(X_test)
```

Binarization

```
>>> from sklearn.preprocessing import Binarizer
>>> binarizer = Binarizer(threshold=0.0).fit(X)
>>> binary_X = binarizer.transform(X)
```

Encoding Categorical Features

```
>>> from sklearn.preprocessing import Imputer
>>> imp = Imputer(missing_values=0, strategy='mean', axis=0)
>>> imp.fit_transform(X_train)
```

Imputing Missing Values

```
>>> from sklearn.preprocessing import Imputer
>>> imp = Imputer(missing_values=0, strategy='mean', axis=0)
>>> imp.fit_transform(X_train)
```

Generating Polynomial Features

```
>>> from sklearn.preprocessing import PolynomialFeatures
>>> poly = PolynomialFeatures(5)
>>> poly.fit_transform(X)
```

Evaluate Your Model's Performance

Classification Metrics

Accuracy Score

```
>>> knn.score(X_test, y_test)
>>> from sklearn.metrics import accuracy_score
>>> accuracy_score(y_test, y_pred)
```

Estimator score method
Metric scoring functions

Classification Report

```
>>> from sklearn.metrics import classification_report
>>> print(classification_report(y_test, y_pred))
```

Precision, recall, f1-score
and support

Confusion Matrix

```
>>> from sklearn.metrics import confusion_matrix
>>> print(confusion_matrix(y_test, y_pred))
```

Regression Metrics

Mean Absolute Error

```
>>> from sklearn.metrics import mean_absolute_error
>>> y_true = [3, -0.5, 2]
>>> mean_absolute_error(y_true, y_pred)
```

Mean Squared Error

```
>>> from sklearn.metrics import mean_squared_error
>>> mean_squared_error(y_test, y_pred)
```

R² Score

```
>>> from sklearn.metrics import r2_score
>>> r2_score(y_true, y_pred)
```

Clustering Metrics

Adjusted Rand Index

```
>>> from sklearn.metrics import adjusted_rand_score
>>> adjusted_rand_score(y_true, y_pred)
```

Homogeneity

```
>>> from sklearn.metrics import homogeneity_score
>>> homogeneity_score(y_true, y_pred)
```

V-measure

```
>>> from sklearn.metrics import v_measure_score
>>> metrics.v_measure_score(y_true, y_pred)
```

Cross-Validation

```
>>> from sklearn.cross_validation import cross_val_score
>>> print(cross_val_score(knn, X_train, y_train, cv=4))
>>> print(cross_val_score(lr, X, y, cv=2))
```

Model Fitting

Supervised learning

```
>>> lr.fit(X, y)
>>> knn.fit(X_train, y_train)
>>> svc.fit(X_train, y_train)
```

Fit the model to the data

Unsupervised Learning

```
>>> k_means.fit(X_train)
>>> pca_model = pca.fit_transform(X_train)
```

Fit the model to the data
Fit to data, then transform it

Create Your Model

Supervised Learning Estimators

Linear Regression

```
>>> from sklearn.linear_model import LinearRegression
>>> lr = LinearRegression(normalize=True)
```

Support Vector Machines (SVM)

```
>>> from sklearn.svm import SVC
>>> svc = SVC(kernel='linear')
```

Naive Bayes

```
>>> from sklearn.naive_bayes import GaussianNB
>>> gnb = GaussianNB()
```

KNN

```
>>> from sklearn import neighbors
>>> knn = neighbors.KNeighborsClassifier(n_neighbors=5)
```

Unsupervised Learning Estimators

Principal Component Analysis (PCA)

```
>>> from sklearn.decomposition import PCA
>>> pca = PCA(n_components=0.95)
```

K Means

```
>>> from sklearn.cluster import KMeans
>>> k_means = KMeans(n_clusters=3, random_state=0)
```

Training And Test Data

```
>> from sklearn.cross_validation import train_test_split
>> X_train, X_test, y_train, y_test = train_test_split(X,
                                                         y,
                                                         random state=0)
```

Tune Your Model

Grid Search

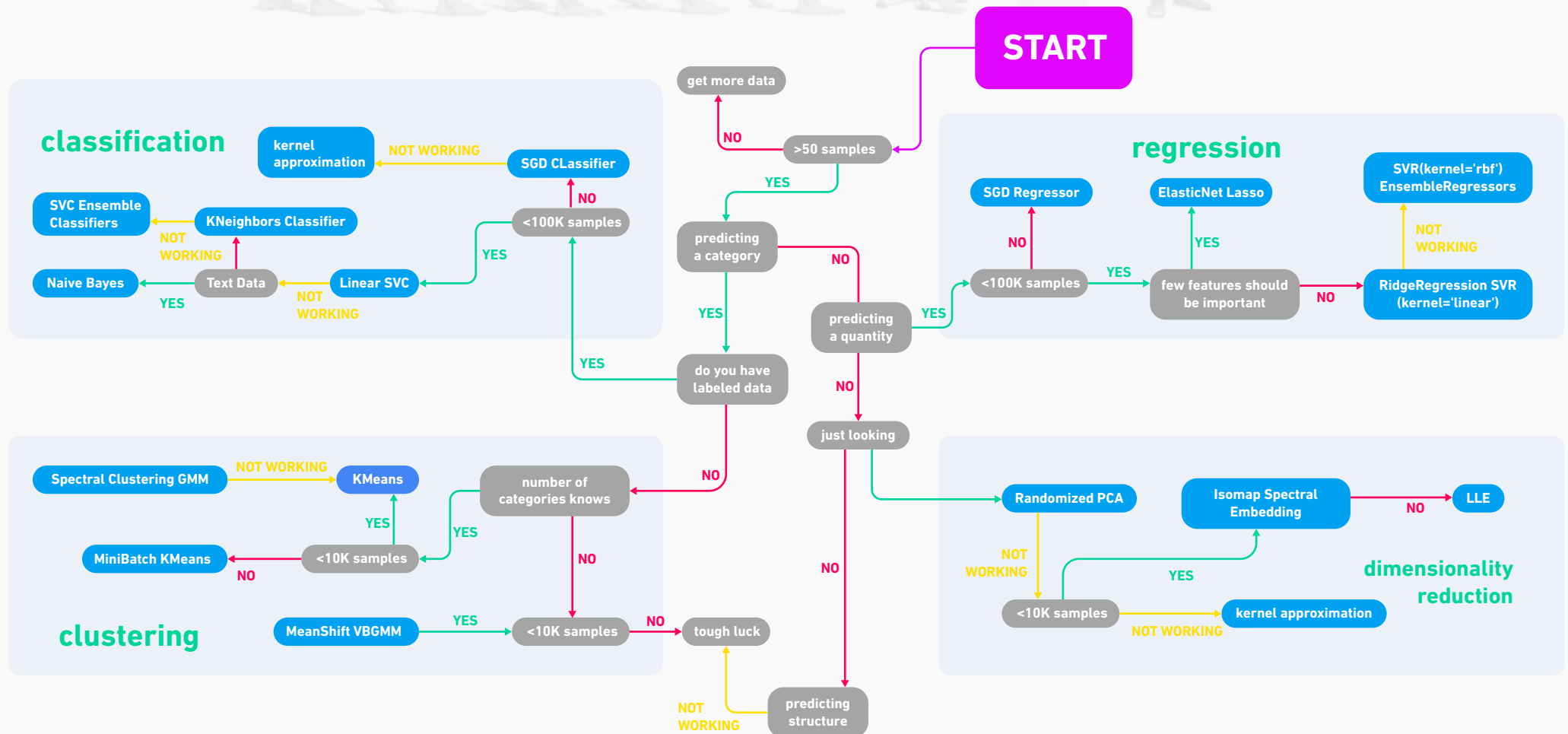
```
>>> from sklearn.grid_search import GridSearchCV
>>> params = [{"n_neighbors": np.arange(1,3),
              "metric": ["euclidean", "cityblock"]}
>>> grid = GridSearchCV(estimator=knn,
                       param_grid=params)
>>> grid.fit(X_train, y_train)
>>> print(grid.best_score_)
>>> print(grid.best_estimator_.n_neighbors)
```

Randomized Parameter Optimization

```
>>> from sklearn.grid_search import RandomizedSearchCV
>>> params = [{"n_neighbors": range(1,5),
              "weights": ["uniform", "distance"]}
>>> rsearch = RandomizedSearchCV(estimator=knn,
                                param_distributions=params,
                                cv=4,
                                n_iter=8,
                                random_state=5)
>>> rsearch.fit(X_train, y_train)
>>> print(rsearch.best_score_)
```


Skicit-learn Algorithm

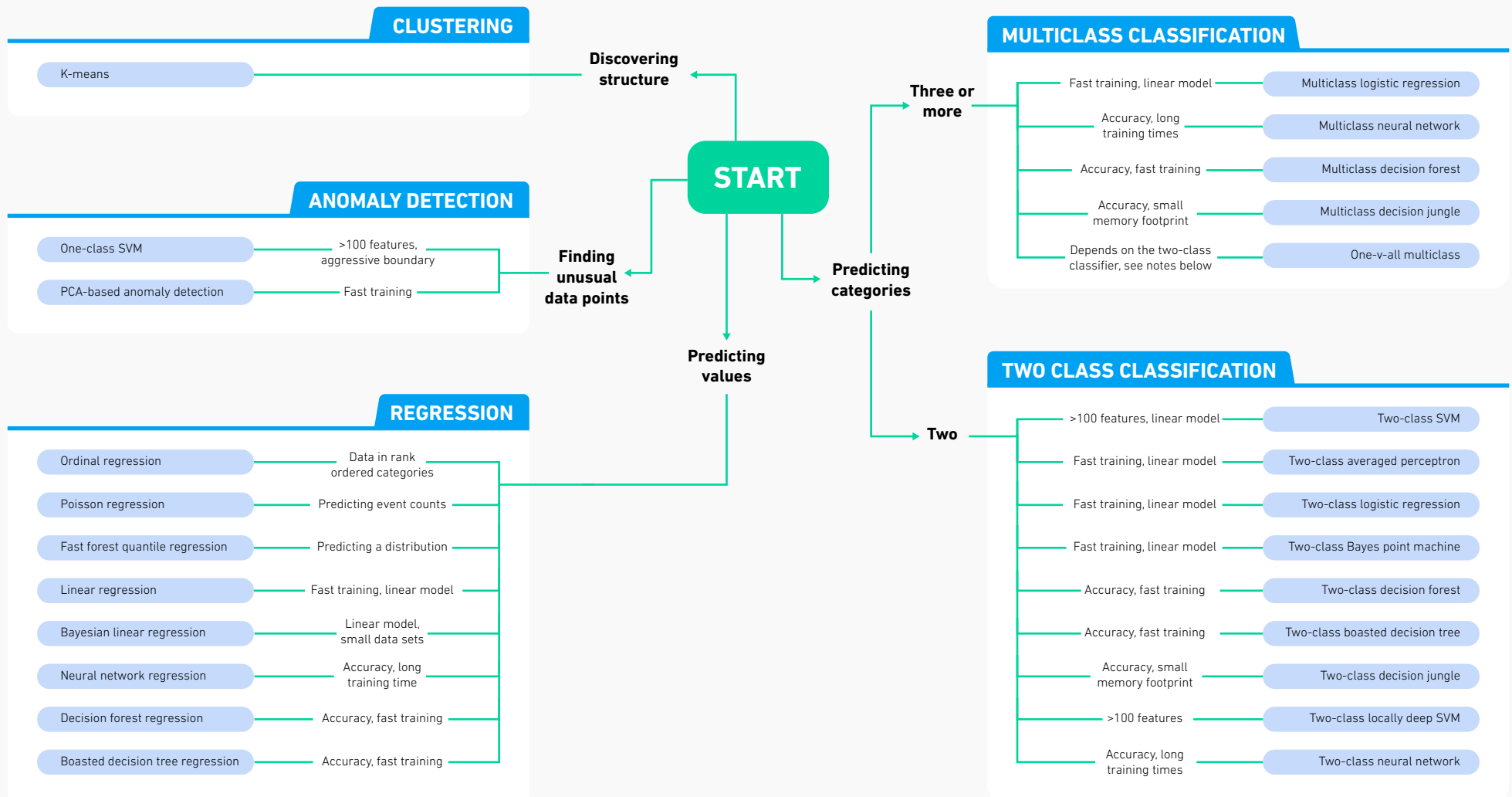
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Algorithm Cheat Sheet

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This cheat sheet helps you choose the best Azure Machine Learning Studio algorithm for your predictive analytics solution. Your decision is driven by both the nature of your data and the question you're trying to answer.



The background is split vertically. The left half is a solid orange color with a faint, dark orange geometric pattern of interconnected lines and dots. The right half is a light grey color with a faint, dark grey geometric pattern of interconnected lines and dots, similar to the one on the left but less dense.

Part 3

Data Science with Python

Tensor Flow Cheat Sheet

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In May 2017 Google announced the second-generation of the TPU, as well as the availability of the TPUs in Google Compute Engine.[12] The second-generation TPUs deliver up to 180 teraflops of performance, and when organized into clusters of 64 TPUs provide up to 11.5 petaflops.

Info

TensorFlow

TensorFlow™ is an open source software library created by Google for numerical computation and large scale computation. Tensorflow bundles together Machine Learning. Deep learning models and frameworks and makes them useful by way of common metaphor.

Keras

Keras is an open sourced neural networks library, written in Python and is built for fast experimentation via deep neural networks and modular design. It is capable of running on top of TensorFlow, Theano, Microsoft Cognitive Toolkit, or PlaidML.

Skflow

Scikit Flow is a high level interface base on tensorflow which can be used like sklearn. You can build you own model on your own data quickly without rewriting extra code.provides a set of high level model classes that you can use to easily integrate with your existing Scikit-learn pipeline code.

Installation

How to install new package in Python

`pip install <package-name>`

Example: `pip install requests`

How to install tensorflow?

`device = cpu/gpu`

`python_version = cp27/cp34`

`sudo pip install`

`https://storage.googleapis.com/tensorflow/linux/$device/tensorflow-0.8.0-$python_version-none-linux_x86_64.whl`
`sudo pip install`

How to install Skflow

`pip install sklearn`

How to install Keras

`pip install keras`

`update ~/.keras/keras.json -- replace "theano" by "tensorflow"`

Helpers

Python helper Important functions

`type(object)`

Get object type

`help(object)`

Get help for object (list of available methods, attributes, signatures and so on)

`dir(object)`

Get list of object attributes (fields, functions)

`str(object)`

Transform an object to string object?

Shows documentations about the object

`globals()`

Return the dictionary containing the current scope's global variables.

`locals()`

Update and return a dictionary containing the current scope's local variables.

`id(object)`

Return the identity of an object. This is guaranteed to be unique among simultaneously existing objects.

`import_builtin_`

`dir(builtins)`

Other built-in functions

Tensor Flow

Main classes

`tf.Graph()`

`tf.Operation()`

`tf.Tensor()`

`tf.Session()`

Some useful functions

`tf.get_default_session()`

`tf.get_default_graph()`

`tf.reset_default_graph()`

`ops.reset_default_graph()`

`tf.device("/cpu:0")`

`tf.name_scope(value)`

`tf.convert_to_tensor(value)`

TensorFlow Optimizers

`GradientDescentOptimizer`

`AdadeltaOptimizer`

`AdagradOptimizer`

`MomentumOptimizer`

`AdamOptimizer`

`FtrlOptimizer`

`RMSPropOptimizer`

Reduction

`reduce_sum`

`reduce_prod`

`reduce_min`

`reduce_max`

`reduce_mean`

`reduce_all`

`reduce_any`

`accumulate_n`

Activation functions

`tf.nn?`

`relu`

`relu6`

`elu`

`softplus`

`softsign`

`dropout`

`bias_add`

`sigmoid`

`tanh`

`sigmoid_cross_entropy_with_logits`

`softmax`

`log_softmax`

`softmax_cross_entropy_with_logits`

`sparse_softmax_cross_entropy_with_logits`

`weighted_cross_entropy_with_logits`

etc.

Skflow

Main classes

`TensorFlowClassifier`

`TensorFlowRegressor`

`TensorFlowDNNClassifier`

`TensorFlowDNNRegressor`

`TensorFlowLinearClassifier`

`TensorFlowLinearRegressor`

`TensorFlowRNNClassifier`

`TensorFlowRNNRegressor`

`TensorFlowEstimator`

Each classifier and regressor have following fields
n_classes=0 (Regressor), n_classes are expected to be input (Classifier)

`batch_size=32,`

`steps=200, // except`

`TensorFlowRNNClassifier - there is 50`

`optimizer='Adagrad',`

`learning_rate=0.1,`

Each class has a method fit

`fit(X, y, monitor=None, logdir=None)`

X: matrix or tensor of shape [n_samples, n_features...]. Can be iterator that returns arrays of features. The training input samples for fitting the model.

Y: vector or matrix [n_samples] or [n_samples, n_outputs]. Can be iterator that returns array of targets. The training target values (class labels in classification, real numbers in regression).

monitor: Monitor object to print training progress and invoke early stopping

logdir: the directory to save the log file that can be used for optional visualization.

`predict(X, axis=1, batch_size=None)`

Args:

X: array-like matrix, [n_samples, n_features...] or iterator. axis: Which axis to argmax for classification.

By default axis 1 (next after batch) is used. Use 2 for sequence predictions.

batch_size: If test set is too big, use batch size to split it into mini batches. By default the batch_size member variable is used.

Returns:

y: array of shape [n_samples]. The predicted classes or predicted value.

Phyton For Data Science

Cheat-Sheet Phyton Basic

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Variables and Data Types

Variable Assignment

```
>>> x=5
>>> x
5
```

Calculations With Variables

>>> x+2	Sum of two variables
7	
>>> x-2	Subtraction of two variables
3	
>>> x*2	Multiplication of two variables
10	
>>> x**2	Exponentiation of a variable
25	
>>> x%2	Remainder of a variable
1	
>>> x/float(2)	Division of a variable
2.5	

Calculations With Variables

str()	'5','3.45','True'	Variables to strings
int()	5, 3, 1	Variables to integers
float()	5.0, 1.0	Variables to floats
bool()	True, True, True	Variables to booleans

Asking For Help

```
>>> help(str)
```

Lists

Also see NumPy Arrays

```
>>> a = 'is'
>>> b = 'nice'
>>> my_list = ['my', 'list', a, b]
>>> my_list2 = [[4,5,6,7], [3,4,5,6]]
```

Selecting List Elements

Index starts at 0

Subset	
>>> my_list[1]	Select item at index 1
>>> my_list[-3]	Select 3rd last item
Slice	
>>> my_list[1:3]	Select items at index 1 and 2
>>> my_list[1:]	Select items after index 0
>>> my_list[:3]	Select items before index 3
>>> my_list[:]	Copy my_list
Subset Lists of Lists	
>>> my_list2[1][0]	my_list[list][itemOfList]
>>> my_list2[1][:2]	

List Operations

```
>>> my_list + my_list
['my', 'list', 'is', 'nice', 'my', 'list', 'is', 'nice']
>>> my_list * 2
['my', 'list', 'is', 'nice', 'my', 'list', 'is', 'nice']
>>> my_list2 > 4
True
```

List Methods

>>> my_list.index(a)	Get the index of an item
>>> my_list.count(a)	Count an item
>>> my_list.append('!')	Append an item at a time
>>> my_list.remove('!')	Remove an item
>>> del(my_list[0:1])	Remove an item
>>> my_list.reverse()	Reverse the list
>>> my_list.extend('!')	Append an item
>>> my_list.pop(-1)	Remove an item
>>> my_list.insert(0,'!')	Insert an item
>>> my_list.sort()	Sort the list

NumPy Arrays

Also see Lists

```
>>> my_list = [1, 2, 3, 4]
>>> my_array = np.array(my_list)
>>> my_2darray =
np.array([[1,2,3],[4,5,6]])
```

Selecting Numpy Array Elements

Index starts at 0

Subset	
>>> my_array[1]	Select item at index 1
2	
Slice	
>>> my_array[0:2]	Select items at index 0 and 1
array([1, 2])	
Subset 2D Numpy arrays	
>>> my_2darray[:,:0]	my_2darray[rows, columns]
array([], [])	

Numpy Array Operations

```
>>> my_array > 3
array([False, False, False,  True], dtype=bool)
>>> my_array * 2
array([2, 4, 6, 8])
>>> my_array + np.array([5, 6, 7, 8])
array([6, 8, 10, 12])
```

Numpy Array Operations

>>> my_array.shape	Get the dimensions of the array
>>> np.append(other_array)	Append items to an array
>>> np.insert(my_array, 1, 5)	Insert items in an array
>>> np.delete(my_array, [1])	Delete items in an array
>>> np.mean(my_array)	Mean of the array
>>> np.median(my_array)	Median of the array
>>> my_array.corrcoef()	Correlation coefficient
>>> np.std(my_array)	Standard deviation

Strings

Also see NumPy Arrays

```
>>> my_string = 'thisStringIsAwesome'
>>> my_string
'thisStringIsAwesome'
```

String Operations

```
>>> my_string * 2
'thisStringIsAwesomethisStringIsAwesome'
>>> my_string + 'Innit'
'thisStringIsAwesomelnnit'
>>> 'm' in my_string
True
```

String Operations

Index starts at 0

```
>>> my_string[3]
>>> my_string[4:9]
```

String Methods

>>> my_string.upper()	String to uppercase
>>> my_string.lower()	String to lowercase
>>> my_string.count('w')	Count String elements
>>> my_string.replace('e', 'i')	Replace String elements
>>> my_string.strip()	Strip whitespaces

Libraries

Import libraries

```
>>> import numpy
>>> import numpy as np
Selective import
>>> from math import pi
```

Install Python



Leading open data science platform powered by Python



Free IDE that is included with Anaconda



Create and share documents with live code, visualizations, text, ...

Python For Data Science Cheat Sheet

PySpark - RDD Basics

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PySpark is the Spark Python API that exposes the Spark programming model to Python.

Initializing Spark

SparkContext

```
>>> from pyspark import SparkContext
>>> sc = SparkContext(master = 'local[2]')
```

Calculations With Variables

>>> sc.version	Retrieve SparkContext version
>>> sc.pythonVer	Retrieve Python version
>>> sc.master	Master URL to connect to
>>> str(sc.sparkHome)	Path where Spark is installed on worker nodes
>>> str(sc.sparkUser())	Retrieve name of the Spark User running SparkContext
>>> sc.appName	Return application name
>>> sc.applicationId	Retrieve application ID
>>> sc.defaultParallelism	Return default level of parallelism
>>> sc.defaultMinPartitions	Default minimum number of partitions for RDDs

Configuration

```
>>> from pyspark import SparkConf, SparkContext
>>> conf = (SparkConf()
...         .setMaster('local')
...         .setAppName('My app')
...         .set('spark.executor.memory', '1g'))
>>> sc = SparkContext(conf = conf)
```

Configuration

In the PySpark shell, a special interpreter-aware SparkContext is already created in the variable called `sc`.

```
$ ./bin/spark-shell --master local[2]
$ ./bin/pyspark --master local[4] --py-files code.py
```

Set which master the context connects to with the `--master` argument, and add Python `.zip`, `.egg` or `.py` files to the runtime path by passing a comma-separated list to `--py-files`.

Loading Data

Parallelized Collections

```
>>> rdd = sc.parallelize([('a':7),('a':2),('b':2)])
>>> rdd2 = sc.parallelize([('a':2),('d':1),('b':1)])
>>> rdd3 = sc.parallelize(range(100))
>>> rdd4 = sc.parallelize([('a':x,y,z),
...                       ('b':['p','r'])])
```

External Data

Read either one text file from HDFS, a local file system or or any Hadoop-supported file system URI with `textFile()`, or read in a directory of text files with `wholeTextFiles()`.

```
>>> textFile = sc.textFile('/my/directory/*txt')
>>> textFile2 = sc.wholeTextFiles('/my/directory/')
```

Selecting Data

Getting

>>> rdd.collect()	Return a list with all RDD elements
[('a', 7), ('a', 2), ('b', 2)]	
>>> rdd.take(2)	Take first 2 RDD elements
[('a', 7), ('a', 2)]	
>>> rdd.first()	Take first RDD element
('a', 7)	
>>> rdd.top(2)	Take top 2 RDD elements
[('b', 2), ('a', 7)]	

Sampling

```
>>> rdd3.sample(False, 0.15, 81).collect()
[3,4,27,31,40,41,42,43,60,76,79,80,86,97]
```

Filtering

>>> rdd.filter(lambda x: "a" in x)	Filter the RDD
.collect()	Return distinct RDD values
[('a',7),('a',2)]	Return (key,value) RDD's keys
>>> rdd5.distinct().collect()	
[a,2,b,7]	
>>> rdd.keys().collect()	
[a, a, b]	

Iterating

Getting

```
>>> def g(x): print(x)
>>> rdd.foreach(g)
('a', 7)
('b', 2)
('a', 2)
```

Retrieving RDD Information

Basic Information

>>> rdd.getNumPartitions()	List the number of partitions
>>> rdd.count()	Count RDD instances
3	
>>> rdd.countByKey()	Count RDD instances by key
defaultdict(<type 'int'>, {'a':2,'b':1})	
>>> rdd.countByValue()	Count RDD instances by value
defaultdict(<type 'int'>, {('b',2):1,('a',2):1,('a',7):1})	
>>> rdd.collectAsMap()	Return (key,value) pairs as a dictionary
{a: 2,b: 2}	
>>> rdd3.sum()	Sum of RDD elements
4950	
>>> sc.parallelize([]).isEmpty()	Check whether RDD is empty
true	

Summary

>>> rdd3.max()	Maximum value of RDD elements
99	
>>> rdd3.min()	Minimum value of RDD elements
0	
>>> rdd3.mean()	Mean value of RDD elements
49.5	
>>> rdd3.stdev()	Standard deviation of RDD elements
28.866070047722118	
>>> rdd3.variance()	Compute variance of RDD elements
833.25	
>>> rdd3.histogram(3)	Compute histogram by bins
[(0,33,66,99),[33,33,34)]	
>>> rdd3.stats()	Summary statistics (count, mean, stdev, max & min)

Applying Functions

>>> rdd.map(lambda x: x+(x[1],x[0]))	Apply a function to each RDD element
.collect()	
[('a',7,7,'a'),(a,2,2,a),('b',2,2,b)]	
>>> rdd5 = rdd.flatMap(lambda x: x+(x[1],x[0]))	Apply a function to each RDD element and flatten the result
>>> rdd5.collect()	
[a,7,7,a,a,2,2,a,b,2,2,b]	
>>> rdd4.flatMapValues(lambda x: x)	Apply a flatMap function to each (key,value) pair of rdd4 without changing the keys
.collect()	
[('a','x'),('a','y'),('a','z'),('b','p'),('b','r')]	

Mathematical Operations

>>> rdd.subtract(rdd2)	Return each rdd value not contained
.collect() in rdd2	
[('b',2),('a',7)]	
>>> rdd2.subtractByKey(rdd)	Return each (key,value) pair of rdd2 with no matching key in rdd
.collect()	
[('d',1)]	
>>> rdd.cartesian(rdd2).collect()	Return the Cartesian product of rdd and rdd2

Sort

>>> rdd2.sortBy(lambda x: x[1])	Sort RDD by given function
.collect()	
[('d',1),('b',1),('a',2)]	
>>> rdd2.sortByKey() Sort (key, value)	RDD by key
.collect()	
[('a',2),('b',1),('d',1)]	

Reshaping Data

Reducing

>>> rdd.reduceByKey(lambda x,y: x+y)	Merge the rdd values for
.collect() each key	
[('a',9),('b',2)]	
>>> rdd.reduce(lambda a, b: a + b)	Merge the rdd values
('a',7,a,2,b,2)	

Grouping by

>>> rdd3.groupBy(lambda x: x % 2)	Return RDD of grouped values
.mapValues(list)	
.collect()	
>>> rdd.groupByKey()	Group rdd by key
.mapValues(list)	
.collect()	
[('a',[7,2]),('b',[2])]	

Aggregating

>>> seqOp = (lambda x,y: (x[0]+y,x[1]+1))	Aggregate RDD elements of each partition and then the results
>>> combOp = (lambda x,y:(x[0]+y[0],x[1]+y[1]))	
>>> rdd3.aggregate((0,0),seqOp,combOp)	Aggregate values of each RDD key
(4950,100)	
>>> rdd.aggregateByKey((0,0),seqOp,combOp)	Aggregate the elements of each 4950 partition, and then the results
.collect()	Merge the values for each key
[('a,(9,2)), ('b,(2,1))]	
>>> rdd3.fold(0,add)	
4950	
>>> rdd.foldByKey(0, add)	
.collect()	
[('a',9),('b',2)]	
>>> rdd3.keyBy(lambda x: x+x)	Create tuples of RDD elements by applying a function
.collect()	

Reshaping Data

>>> rdd.repartition(4)	New RDD with 4 partitions
>>> rdd.coalesce(1)	Decrease the number of partitions in the RDD to 1

Saving

```
>>> rdd.saveAsTextFile('rdd.txt')
>>> rdd.saveAsHadoopFile('hdfs://namenodehost/parent/child',
...                      'org.apache.hadoop.mapred.TextOutputFormat')
```

Stopping SparkContext

```
>>> sc.stop()
```

Execution

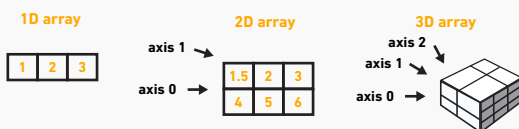
```
$ ./bin/spark-submit examples/src/main/python/pi.py
```

NumPy Basics Cheat Sheet

BecomingHuman.AI



The NumPy library is the core library for scientific computing in Python. It provides a high-performance multidimensional array object, and tools for working with these arrays.



Creating Arrays

```
>>> a = np.array([1,2,3])
>>> b = np.array([(1.5,2,3), (4,5,6)], dtype = float)
>>> c = np.array([[(1.5,2,3), (4,5,6)], [(3,2,1), (4,5,6)]], dtype = float)
```

Initial Placeholders

```
>>> np.zeros((3,4))           Create an array of zeros
>>> np.ones((2,3,4), dtype=np.int16) Create an array of ones
>>> d = np.arange(10,25,5)     Create an array of evenly spaced values (step value)
>>> np.linspace(0,2,9)        Create an array of evenly spaced values (number of samples)
>>> e = np.full((2,2),7)       Create a constant array
>>> f = np.eye(2)              Create a 2X2 identity matrix
>>> np.random.random((2,2))    Create an array with random values
>>> np.empty((3,2))            Create an empty array
```

I/O

Saving & Loading On Disk

```
>>> np.save('my_array', a)
>>> np savez('array.npz', a, b)
>>> np.load('my_array.npy')
```

Saving & Loading Text Files

```
>>> np.loadtxt('myfile.txt')
>>> np.genfromtxt('my_file.csv', delimiter=',')
>>> np.savetxt('myarray.txt', a, delimiter='')
```

Inspecting Your Array

```
>>> a.shape           Array dimensions
>>> len(a)             Length of array
>>> b.ndim             Number of array dimensions
>>> e.size             Number of array elements
>>> b.dtype            Data type of array elements
>>> b.dtype.name       Name of data type
>>> b.astype(int)      Convert an array to a different type
```

Data Types

```
>>> np.int64           Signed 64-bit integer types
>>> np.float32         Standard double-precision floating point
>>> np.complex         Complex numbers represented by 128 floats
>>> np.bool            Boolean type storing TRUE and FALSE
>>> np.object          Python object type values
>>> np.string_         Fixed-length string type
>>> np.unicode_        Fixed-length unicode type
```

Asking For Help

```
>>> np.info(np.ndarray.dtype)
```

Array Mathematics

Arithmetic Operations

```
>>> g = a - b          Subtraction
array([[ -0.5,  0. ,  0. ],
       [ -3. , -3. , -3. ]])

>>> np.subtract(a,b)    Subtraction

>>> b + a              Addition
array([[ 2.5,  4. ,  6. ],
       [ 5. ,  7. ,  9. ]])

>>> np.add(b,a)         Addition

>>> a / b              Division
array([[ 0.66666667,  1. ,  1. ],
       [ 0.25 ,  0.4 ,  0.5 ]])

>>> np.divide(a,b)      Division

>>> a * b              Multiplication
array([[ 4. , 10. , 18. ]])

>>> np.multiply(a,b)    Multiplication
>>> np.exp(b)           Exponentiation
>>> np.sqrt(b)          Square root
>>> np.sin(a)           Print sines of an array
>>> np.cos(b)           Element-wise cosine
>>> np.log(a)           Element-wise natural logarithm
>>> np.dot(f)           Dot product
array([[ 7. ,  7. ]])
```

Comparison

```
>>> a == b             Element-wise comparison
array([[False,  True,  True],
       [False, False, False]], dtype=bool)

>>> a < 2             Element-wise comparison
array([ True, False, False], dtype=bool)

>>> np.array_equal(a, b) Array-wise comparison
```

Aggregate Functions

```
>>> a.sum()            Array-wise sum
>>> a.min()            Array-wise minimum value
>>> b.max(axis=0)       Maximum value of an array row
>>> b.cumsum(axis=1)    Cumulative sum of the elements
>>> a.mean()           Mean
>>> b.median()         Median
```

Copying Arrays

```
>>> h = a.view()       Create a view of the array with the same data
>>> np.copy(a)         Create a copy of the array
>>> h = a.copy()       Create a deep copy of the array
```

Sorting Arrays

```
>>> a.sort()           Sort an array
>>> c.sort(axis=0)     Sort the elements of an array's axis
```

Subsetting, Slicing, Indexing

Subsetting

```
>>> a[2]              Select the element at the 2nd index
3

>>> b[1,2]            Select the element at row 1 column 2
6.0                    (equivalent to b[1][2])
```

Slicing

```
>>> a[0:2]            Select items at index 0 and 1
array([1, 2])

>>> b[0:2,1]          Select items at rows 0 and 1 in column 1
array([[2., 5.]])

>>> b[:,1]            Select all items at row 0
array([[1.5, 2., 3.]])    (equivalent to b[0:1,:])
>>> c[1,...]          Same as [1,::]
array([[[ 3., 2., 1. ],
        [ 4., 5., 6. ]]])
```

```
>>> a[::-1]           Reversed array a
array([3, 2, 1])
```

Boolean Indexing

```
>>> a[a<2]            Select elements from a less than 2
array([1])
```

Fancy Indexing

```
>>> b[[1,0,1,0],[0,1,2,0]] Select elements (1,0),(0,1),(1,2) and (0,0)
array([ 4.,  2.,  6.,  1.5])

>>> b[[1,0,1,0]][:,[0,1,2,0]] Select a subset of the matrix's rows
array([[ 4.,  5.,  6.,  4. ],    and columns
       [ 1.5,  2.,  3.,  1.5],
       [ 4.,  5.,  6.,  4. ],
       [ 1.5,  2.,  3.,  1.5]])
```

Array Manipulation

Transposing Array

```
>>> i = np.transpose(b) Permute array dimensions
>>> i.T                 Permute array dimensions
```

Adding/Removing Elements

```
>>> h.resize((2,6))     Return a new array with shape (2,6)
>>> np.append(h,g)      Append items to an array
>>> np.insert(a, 1, 5)    Insert items in an array
>>> np.delete(a,[1])     Delete items from an array
```

Splitting Arrays

```
>>> np.hsplit(a,3)       Split the array horizontally at the 3rd
array([1]), array([2]), array([3])) index

>>> np.vsplit(c,2)       Split the array vertically at the 2nd index
array([[[ 1.5,  2. ,  1. ],
        [ 4. ,  5. ,  6. ]]]),
```

Changing Array Shape

```
>>> b.ravel()           Flatten the array
>>> g.reshape(3,-2)     Reshape, but don't change data
```

Combining Arrays

```
>>> np.concatenate((a,d),axis=0) Concatenate arrays
array([ 1,  2,  3, 10, 15, 20])

>>> np.vstack((a,b))    Stack arrays vertically (row-wise)
array([[ 1. ,  2. ,  3. ],
       [ 1.5,  2.,  3. ],
       [ 4. ,  5. ,  6. ]])

>>> np.r_[e,f]          Stack arrays vertically (row-wise)
>>> np.hstack((e,f))    Stack arrays horizontally (column-wise)
array([[ 7.,  7.,  0.,  1.]])

>>> np.column_stack((a,d)) Create stacked column-wise arrays
array([[ 1, 10],
       [ 2, 15],
       [ 3, 20]])

>>> np.c_[a,d]          Create stacked column-wise arrays
```



Bokeh Cheat Sheet

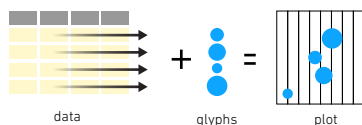
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Data Types

The Python interactive visualization library **Bokeh** enables high-performance visual presentation of large datasets in modern web browsers.

Bokeh's mid-level general purpose bokeh.plotting interface is centered around two main components: data and glyphs.



The basic steps to creating plots with the bokeh.plotting interface are:

1. Prepare some data:
Python lists, NumPy arrays, Pandas DataFrames and other sequences of values
2. Create a new plot
3. Add renderers for your data, with visual customizations
4. Specify where to generate the output
5. Show or save the results

```
>>> from bokeh.plotting import figure
>>> from bokeh.io import output_file, show
>>> x = [1, 2, 3, 4, 5]
>>> y = [6, 7, 2, 4, 5]
>>> p = figure(title='simple line example',
>>>             x_axis_label='x',
>>>             y_axis_label='y')
>>> p.line(x, y, legend='Temp', line_width=2)
>>> output_file('lines.html')
>>> show(p)
```

Data

Also see Lists, NumPy & Pandas

Under the hood, your data is converted to Column Data Sources. You can also do this manually:

```
>>> import numpy as np
>>> import pandas as pd
>>> df = pd.DataFrame(np.array([[33.9, 4.65, 'US'],
>>>                             [32.4, 4.66, 'Asia'],
>>>                             [21.4, 4.109, 'Europe']]),
>>>                   columns=['mpg', 'cyl', 'hp', 'origin'],
>>>                   index=['Toyota', 'Fiat', 'Volvo'])
>>> from bokeh.models import ColumnDataSource
>>> cds_df = ColumnDataSource(df)
```

Plotting

```
>>> from bokeh.plotting import figure
>>> p1 = figure(plot_width=300, tools='pan, box_zoom')
>>> p2 = figure(plot_width=300, plot_height=300,
>>>             x_range=(0, 8), y_range=(0, 8))
>>> p3 = figure()
```

Show or Save Your Plots

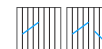
```
>>> show(p1)
>>> show(layout)
>>> save(p1)
>>> save(layout)
```

Renderers & Visual Customizations

Glyphs



```
Scatter Markers
>>> p1.circle(np.array([1, 2, 3]), np.array([3, 2, 1]),
>>>            fill_color='white')
>>> p2.square(np.array([1.5, 3.5, 5.5]), [1, 4, 3],
>>>            color='blue', size=1)
```



```
Line Glyphs
>>> p1.line([1, 2, 3, 4], [3, 4, 5, 6], line_width=2)
>>> p2.multi_line(pd.DataFrame([[1, 2, 3], [5, 6, 7]]),
>>>                pd.DataFrame([[3, 4, 5], [3, 2, 1]]),
>>>                color='blue')
```

Rows & Columns Layout

Rows

```
>>> from bokeh.layouts import row
>>> layout = row(p1, p2, p3)
```

Columns

```
>>> from bokeh.layouts import columns
>>> layout = column(p1, p2, p3)
```

Nesting Rows & Columns

```
>>> layout = row(column(p1, p2), p3)
```

Grid Layout

```
>>> from bokeh.layouts import gridplot
>>> row1 = [p1, p2]
>>> row2 = [p3]
>>> layout = gridplot([[p1, p2], [p3]])
```

Legends

Legend Location

Inside Plot Area

```
>>> p.legend.location = "bottom_left"
```

Outside Plot Area

```
>>> r1 = p2.asterisk(np.array([1, 2, 3]), np.array([3, 2, 1]))
>>> r2 = p2.line([1, 2, 3, 4], [3, 4, 5, 6])
>>> legend = Legend(items=[('One', [p1, r1]), ('Two', [r2])], location=(0, -30))
>>> p.add_layout(legend, 'right')
```

Customized Glyphs

Also see data



```
Selection and Non-Selection Glyphs
>>> p = figure(tools='box_select')
>>> p.circle('mpg', 'cyl', source=cds_df,
>>>           selection_color='red',
>>>           nonselection_alpha=0.1)
```



```
Hover Glyphs
>>> hover = HoverTool(tooltips=None, mode='vline')
>>> p3.add_tools(hover)
```



```
Colormapping
>>> color_mapper = CategoricalColorMapper(
>>>     factors=['US', 'Asia', 'Europe'],
>>>     palette=['blue', 'red', 'green'])
>>> p3.circle('mpg', 'cyl', source=cds_df,
>>>            color=dict(field='origin',
>>>                        transform=color_mapper),
>>>            legend='Origin')
```

Linked Plots

Also see data

Linked Axes

```
>>> p2.x_range = p1.x_range
>>> p2.y_range = p1.y_range
```

Linked Brushing

```
>>> p4 = figure(plot_width = 100, tools='box_select, lasso_select')
>>> p4.circle('mpg', 'cyl', source=cds_df)
>>> p5 = figure(plot_width = 200, tools='box_select, lasso_select')
```

Tabbed Layout

```
>>> from bokeh.models.widgets import Panel, Tabs
>>> tab1 = Panel(child=p1, title='tab1')
>>> tab2 = Panel(child=p2, title='tab2')
>>> layout = Tabs(tabs=[tab1, tab2])
```

Output

Output to HTML File

```
>>> from bokeh.io import output_file, show
>>> output_file('my_bar_chart.html', mode='cdn')
```

Notebook Output

```
>>> from bokeh.io import output_notebook, show
>>> output_notebook()
```

Standalone HTML

```
>>> from bokeh.embed import file_html
>>> html = file_html(p, CDN, 'my_plot')
```

Components

```
>>> from bokeh.embed import components
>>> script, div = components(p)
```

Statistical Charts With Bokeh

Also see Data

Bokeh's high-level bokeh.charts interface is ideal for quickly creating statistical charts



```
Bar Chart
>>> from bokeh.charts import Bar
>>> p = Bar(df, stacked=True, palette=['red', 'blue'])
```



```
Box Plot
>>> from bokeh.charts import BoxPlot
>>> p = BoxPlot(df, values='vals', label='cyl',
>>>             legend='bottom_right')
```



```
Histogram
>>> from bokeh.charts import Histogram
>>> p = Histogram(df, title='Histogram')
```



```
Scatter Plot
>>> from bokeh.charts import Scatter
>>> p = Scatter(df, x='mpg', y='hp',
>>>             marker='square',
>>>             xlabel='Miles Per Gallon',
```

Keras Cheat Sheet

BecomingHuman.AI



K Keras is a powerful and easy-to-use deep learning library for Theano and TensorFlow that provides a high-level neural networks API to develop and evaluate deep learning models.

A Basic Example

```
>>> import numpy as np
>>> from keras.models import Sequential
>>> from keras.layers import Dense
>>> data = np.random.random((1000,100))
>>> labels = np.random.randint(2,size=(1000,1))
>>> model = Sequential()
>>> model.add(Dense(32,
                    activation='relu',
                    input_dim=100))
>>> model.add(Dense(1, activation='sigmoid'))
>>> model.compile(optimizer='rmsprop',
                 loss='binary_crossentropy',
                 metrics=['accuracy'])
```

Data

Also see NumPy, Pandas & Scikit-Learn

Your data needs to be stored as NumPy arrays or as a list of NumPy arrays. Ideally, you split the data in training and test sets, for which you can also resort to the `train_test_split` module of `sklearn.cross_validation`.

Keras Data Sets

```
>>> from keras.datasets import boston_housing,
mnist,
cifar10,
imdb

>>> (x_train,y_train),(x_test,y_test) = mnist.load_data()
>>> (x_train2,y_train2),(x_test2,y_test2) = boston_housing.load_data()
>>> (x_train3,y_train3),(x_test3,y_test3) = cifar10.load_data()
>>> (x_train4,y_train4),(x_test4,y_test4) = imdb.load_data(num_words=20000)
>>> num_classes = 10
>>> model.fit(data,labels,epochs=10,batch_size=32)
>>> predictions = model.predict(data)
```

Other

```
>>> from urllib.request import urlopen
>>> data = np.loadtxt(urlopen('http://archive.ics.uci.edu/
ml/machine-learning-databases/pima-indians-diabetes/
pima-indians-diabetes.data'),delimiter=',')
>>> X = data[:,0:8]
>>> y = data[:,8]
```

Model Architecture

Sequential Model

```
>>> from keras.models import Sequential
>>> model = Sequential()
>>> model2 = Sequential()
>>> model3 = Sequential()
```

Multilayer Perceptron (MLP)

Binary Classification

```
>>> from keras.layers import Dense
>>> model.add(Dense(12,
                  input_dim=8,
                  kernel_initializer='uniform',
                  activation='relu'))
>>> model.add(Dense(8,kernel_initializer='uniform',activation='relu'))
>>> model.add(Dense(1,kernel_initializer='uniform',activation='sigmoid'))
```

Multi-Class Classification

```
>>> from keras.layers import Dropout
>>> model.add(Dense(512,activation='relu',input_shape=(784,)))
>>> model.add(Dropout(0.2))
>>> model.add(Dense(512,activation='relu'))
>>> model.add(Dropout(0.2))
>>> model.add(Dense(10,activation='softmax'))
```

Regression

```
>>> model.add(Dense(64,activation='relu',input_dim=train_data.shape[1]))
>>> model.add(Dense(1))
```

Convolutional Neural Network (CNN)

```
>>> from keras.layers import Activation,Conv2D,MaxPooling2D,Flatten
>>> model2.add(Conv2D(32,(3,3),padding='same',input_shape=x_train.shape[1:]))
>>> model2.add(Activation('relu'))
>>> model2.add(Conv2D(32,(3,3)))
>>> model2.add(Activation('relu'))
>>> model2.add(MaxPooling2D(pool_size=(2,2)))
>>> model2.add(Dropout(0.25))
>>> model2.add(Conv2D(64,(3,3),padding='same'))
>>> model2.add(Activation('relu'))
>>> model2.add(Conv2D(64,(3,3)))
>>> model2.add(Activation('relu'))
>>> model2.add(MaxPooling2D(pool_size=(2,2)))
>>> model2.add(Dropout(0.25))
>>> model2.add(Flatten())
>>> model2.add(Dense(512))
>>> model2.add(Activation('relu'))
>>> model2.add(Dropout(0.5))
>>> model2.add(Dense(num_classes))
>>> model2.add(Activation('softmax'))
```

Recurrent Neural Network (RNN)

```
>>> from keras.layers import Embedding,LSTM
>>> model3.add(Embedding(20000,128))
>>> model3.add(LSTM(128,dropout=0.2,recurrent_dropout=0.2))
>>> model3.add(Dense(1,activation='sigmoid'))
```

Inspect Model

```
>>> model.output_shape
>>> model.summary()
>>> model.get_config()
>>> model.get_weights()
```

Model output shape
Model summary representation
Model configuration
List all weight tensors in the model

Prediction

```
>>> model3.predict(x_test4, batch_size=32)
>>> model3.predict_classes(x_test4,batch_size=32)
```

Model Fine-tuning

Optimization Parameters

```
>>> from keras.optimizers import RMSprop
>>> opt = RMSprop(lr=0.0001, decay=1e-6)
>>> model2.compile(loss='categorical_crossentropy',
                  optimizer=opt,
                  metrics=['accuracy'])
```

Early Stopping

```
>>> from keras.callbacks import EarlyStopping
>>> early_stopping_monitor = EarlyStopping(patience=2)
>>> model3.fit(x_train4,
              y_train4,
              batch_size=32,
              epochs=15,
              validation_data=(x_test4,y_test4),
              callbacks=[early_stopping_monitor])
```

Compile Model

MLP: Binary Classification

```
>>> model.compile(optimizer='adam',
                 loss='binary_crossentropy',
                 metrics=['accuracy'])
```

MLP: Multi-Class Classification

```
>>> model.compile(optimizer='rmsprop',
                 loss='categorical_crossentropy',
                 metrics=['accuracy'])
```

MLP: Regression

```
>>> model.compile(optimizer='rmsprop',
                 loss='mse',
                 metrics=['mae'])
```

Recurrent Neural Network

```
>>> model3.compile(loss='binary_crossentropy',
                  optimizer='adam',
                  metrics=['accuracy'])
```

Save/ Reload Models

```
>>> from keras.models import load_model
>>> model3.save('model_file.h5')
>>> my_model = load_model('my_model.h5')
```

Model Training

```
>>> model3.fit(x_train4,
              y_train4,
              batch_size=32,
              epochs=15,
              verbose=1,
              validation_data=(x_test4,y_test4))
```

Evaluate Your Model's Performance

```
>>> score = model3.evaluate(x_test,
                           y_test,
                           batch_size=32)
```

Preprocessing

Sequence Padding

```
>>> from keras.preprocessing import sequence
>>> x_train4 = sequence.pad_sequences(x_train4,maxlen=80)
>>> x_test4 = sequence.pad_sequences(x_test4,maxlen=80)
```

One-Hot Encoding

```
>>> from keras.utils import to_categorical
>>> Y_train = to_categorical(y_train, num_classes)
>>> Y_test = to_categorical(y_test, num_classes)
>>> Y_train3 = to_categorical(y_train3, num_classes)
>>> Y_test3 = to_categorical(y_test3, num_classes)
```

Train and Test Sets

```
>>> from sklearn.model_selection import train_test_split
>>> X_train5,X_test5,y_train5,y_test5 = train_test_split(X,
                                                         y,
                                                         test_size=0.33,
                                                         random_state=42)
```

Standardization/Normalization

```
>>> from sklearn.preprocessing import StandardScaler
>>> scaler = StandardScaler().fit(x_train2)
>>> standardized_X = scaler.transform(x_train2)
>>> standardized_X_test = scaler.transform(x_test2)
```

Pandas Basics Cheat Sheet

BecomingHuman.AI



Use the following import convention: `>>> import pandas as pd`

The Pandas library is built on NumPy and provides easy-to-use data structures and data analysis tools for the Python programming language.

Pandas Data Structures

Series

A one-dimensional
labeled array a
capable of holding any
data type

```
>>> s = pd.Series([3, -5, 7, 4], index=['a', 'b', 'c', 'd'])
```

Data Frame

A two-dimensional
labeled data structure
with columns of
potentially different
types

```
>>> data = {'Country': ['Belgium', 'India', 'Brazil'],  
           'Capital': ['Brussels', 'New Delhi', 'Brasilia'],  
           'Population': [11190846, 1303171035, 207847528]}  
>>> df = pd.DataFrame(data,  
                      columns=['Country', 'Capital', 'Population'])
```

	Belgium	Capital	Population
0	Belgium	Brussels	11190846
1	India	New Delhi	1303171035
2	Brazil	Brasilia	207847528

Dropping

```
>>> s.drop(['a', 'c'])           Drop values from rows (axis=0)  
>>> df.drop('Country', axis=1)  Drop values from columns (axis=1)
```

Sort & Rank

```
>>> df.sort_index()           Sort by labels along an axis  
>>> df.sort_values(by='Country') Sort by the values along an axis  
>>> df.rank()                 Assign ranks to entries
```

Retrieving Series/ DataFrame Information

```
>>> df.shape                 (rows, columns)  
>>> df.index                 Describe index  
>>> df.columns               Describe DataFrame columns  
>>> df.info()                Info on DataFrame  
>>> df.count()               Number of non-NA values
```

Summary

```
>>> df.sum()                 Sum of values  
>>> df.cumsum()              Cumulative sum of values  
>>> df.min()/df.max()        Minimum/maximum values  
>>> df.idxmin()/df.idxmax()  Minimum/Maximum index value  
>>> df.describe()            Summary statistics  
>>> df.mean()                 Mean of values  
>>> df.median()               Median of values
```

Selection

Also see NumPy Arrays

Getting

```
>>> s[b]                     Get one element  
-5  
>>> df[1:]                   Get subset of a DataFrame  
   Country Capital  Population  
1  India   New Delhi  1303171035  
2  Brazil  Brasilia   207847528
```

Selecting, Boolean Indexing & Setting

By Position
`>>> df.iloc[[0],[0]]` Select single value by row & column
'Belgium'
`>>> df.iat[[0],[0]]`
'Belgium'

By Label
`>>> df.loc[[0], ['Country']]` Select single value by row & column labels
'Belgium'
`>>> df.at[[0], ['Country']]` 'Belgium'

By Label/Position
`>>> df.ix[2]` Select single row of subset of rows
 Country Brazil
 Capital Brasilia
 Population 207847528

`>>> df.ix[:, 'Capital']` Select a single column of subset of columns
0 Brussels
1 New Delhi
2 Brasilia
`>>> df.ix[1, 'Capital']` Select rows and columns
'New Delhi'

Boolean Indexing
`>>> s[~(s > 1)]` Series s where value is not >1
`>>> s[(s < -1) | (s > 2)]` s where value is <-1 or >2
`>>> df[df['Population'] > 1200000000]` Use filter to adjust DataFrame

Setting
`>>> s['a'] = 6` Set index a of Series s to 6

Asking For Help

```
>>> help(pd.Series.loc)
```

Applying Functions

```
>>> f = lambda x: x*2  
>>> df.apply(f)           Apply function  
>>> df.applymap(f)        Apply function element-wise
```

Data Alignment

Internal Data Alignment

NA values are introduced in the indices that don't overlap:
`>>> s3 = pd.Series([7, -2, 3], index=['a', 'c', 'd'])`

```
>>> s + s3  
a 10.0  
b NaN  
c 5.0  
d 7.0
```

Arithmetic Operations with Fill Methods

You can also do the internal data alignment yourself with the help of the fill methods:

```
>>> s.add(s3, fill_value=0)  
a 10.0  
b -5.0  
c 5.0  
d 7.0  
>>> s.sub(s3, fill_value=2)  
>>> s.div(s3, fill_value=4)
```

I/O

Read and Write to CSV

```
>>> pd.read_csv('file.csv', header=None, nrows=5)  
>>> df.to_csv('myDataFrame.csv')
```

Read and Write to Excel

```
>>> pd.read_excel('file.xlsx')  
>>> pd.to_excel('dir/myDataFrame.xlsx', sheet_name='Sheet1')
```

Read multiple sheets from the same file

```
>>> xlsx = pd.ExcelFile('file.xls')  
>>> df = pd.read_excel(xlsx, 'Sheet1')
```

Read and Write to SQL Query or Database Table

```
>>> from sqlalchemy import create_engine  
>>> engine = create_engine('sqlite:///memory:')  
>>> pd.read_sql("SELECT * FROM my_table;", engine)  
>>> pd.read_sql_table('my_table', engine)  
>>> pd.read_sql_query("SELECT * FROM my_table;", engine)
```

`read_sql()` is a convenience wrapper around `read_sql_table()` and `read_sql_query()`

```
>>> pd.to_sql('myDf', engine)
```


Pandas

Cheat Sheet

BecomingHuman.AI

Pandas Data Structures

Pivot

```
>>> df3 = df2.pivot(index='Date',
                    columns='Type',
                    values='Value')
```

Spread rows into columns

	Date	Type	Value
0	2016-03-01	a	11.432
1	2016-03-02	b	13.031
2	2016-03-01	c	20.784
3	2016-03-03	a	99.906
4	2016-03-02	a	1.303
5	2016-03-03	c	20.784

	Type	a	b	c
2016-03-01		11.432	NaN	20.784
2016-03-02		1.303	13.031	NaN
2016-03-03		99.906	NaN	20.784

Pivot Table

```
>>> df4 = pd.pivot_table(df2,
                        values='Value',
                        index='Date',
                        columns='Type')
```

Spread rows into columns

		0	1
1	5	0.233482	0.390959
2	4	0.184713	0.237102
3	3	0.433522	0.429401

Unstacked

1	5	0	0.233482
		1	0.390959
2	4	0	0.184713
		1	0.237102
3	3	0	0.433522
		1	0.429401

Stacked

Melt

```
>>> pd.melt(df2,
            id_vars=['Date'],
            value_vars=['Type', 'Value'],
            value_name='Observations')
```

Gather columns into rows

	Date	Type	Value
0	2016-03-01	a	11.432
1	2016-03-02	b	13.031
2	2016-03-01	c	20.784
3	2016-03-03	a	99.906
4	2016-03-02	a	1.303
5	2016-03-03	c	20.784

	Date	Variable	Observations
0	2016-03-01	Type	a
1	2016-03-02	Type	b
2	2016-03-01	Type	c
3	2016-03-03	Type	a
4	2016-03-02	Type	a
5	2016-03-03	Type	c
6	2016-03-01	Value	11.432
7	2016-03-02	Value	13.031
8	2016-03-01	Value	20.784
9	2016-03-03	Value	99.906
10	2016-03-02	Value	1.303
11	2016-03-03	Value	20.784

Advanced Indexing

Also see NumPy Arrays

Selecting

```
>>> df3.loc[:,(df3>1).any()]
>>> df3.loc[:,(df3>1).all()]
>>> df3.loc[:,df3.isnull().any()]
>>> df3.loc[:,df3.notnull().all()]
```

Select cols with any vals > 1
Select cols with vals > 1
Select cols with NaN
Select cols without NaN

Indexing With isin

```
>>> df[(df.Country.isin(df2.Type))]
>>> df3.filter(items=['a','b'])
>>> df.select(lambda x: not x%5)
```

Find same elements
Filter on values
Select specific elements

Where

```
>>> s.where(s > 0)
```

Subset the data

Query

```
>>> df6.query('second > first')
```

Query DataFrame

Setting/Resetting Index

```
>>> df.set_index('Country')
>>> df4 = df.reset_index()
>>> df = df.rename(index=str,
                  columns={'Country':'cntry',
                           'Capital':'cptl',
                           'Population':'pptn'})
```

Set the index
Reset the index
Rename DataFrame

Reindexing

```
>>> s2 = s.reindex(['a','c','d','e','b'])
```

Forward Filling

```
>>> df.reindex(range(4),
               method='ffill')
```

```
>>> s3 = s.reindex(range(5),
                  method='bfill')
```

```
Country Capital Population
0 Belgium Brussels 11190846
1 India New Delhi 1303171035
2 Brazil Brasilia 207847528
3 Brazil Brasilia 207847528
```

```
0 3
1 3
2 3
3 3
4 3
```

Multindexing

```
>>> arrays = [np.array([1,2,3]),
              np.array([5,4,3])]
>>> df5 = pd.DataFrame(np.random.rand(3, 2), index=arrays)
>>> tuples = list(zip(*arrays))
>>> index = pd.MultiIndex.from_tuples(tuples,
                                     names=['first', 'second'])
>>> df6 = pd.DataFrame(np.random.rand(3, 2), index=index)
>>> df2.set_index(['Date', 'Type'])
```

Duplicate Data

```
>>> s3.unique()
>>> df2.duplicated('Type')
>>> df2.drop_duplicates('Type', keep='last')
>>> df.index.duplicated()
```

Return unique values
Check duplicates
Drop duplicates
Drop duplicates

Grouping Data

Aggregation

```
>>> df2.groupby(by=['Date','Type']).mean()
>>> df4.groupby(level=0).sum()
>>> df4.groupby(level=0).agg({'a':lambda x:sum(x)/len(x), 'b': np.sum})
```

Transformation

```
>>> customSum = lambda x: (x+x%2)
>>> df4.groupby(level=0).transform(customSum)
```

Missing Data

```
>>> df.dropna()
>>> df3.fillna(df3.mean())
>>> df2.replace("a", "f")
```

Drop NaN value
Fill NaN values with a predetermined value
Replace values with others

Combining Data

data1		data2	
X1	X2	X1	X3
a	11.432	a	20.784
b	1.303	b	NaN
c	99.906	d	20.784

Pivot

```
>>> pd.merge(data1,
            data2,
            how='left',
            on='X1')
```

	X1	X2	X3
a	a	11.432	20.784
b	b	1.303	NaN
c	c	99.906	NaN

```
>>> pd.merge(data1,
            data2,
            how='right',
            on='X1')
```

	X1	X2	X3
a	a	11.432	20.784
b	b	1.303	NaN
d	d	NaN	20.784

```
>>> pd.merge(data1,
            data2,
            how='inner',
            on='X1')
```

	X1	X2	X3
a	a	11.432	20.784
b	b	1.303	NaN

```
>>> pd.merge(data1,
            data2,
            how='outer',
            on='X1')
```

	X1	X2	X3
a	a	11.432	20.784
b	b	1.303	NaN
c	c	99.906	NaN
d	d	NaN	20.784

Join

```
>>> data1.join(data2, how='right')
```

Concatenate

Vertical

```
>>> s.append(s2)
```

Horizontal/Vertical

```
>>> pd.concat([s,s2],axis=1, keys=['One','Two'])
>>> pd.concat([data1, data2], axis=1, join='inner')
```

Dates

```
>>> df2['Date'] = pd.to_datetime(df2['Date'])
>>> df2['Date'] = pd.date_range('2000-1-1', periods=6,
                              freq='M')
>>> dates = [datetime(2012,5,1), datetime(2012,5,2)]
>>> index = pd.DatetimeIndex(dates)
>>> index = pd.date_range(datetime(2012,2,1), end, freq='BM')
```

Visualization

```
>>> import matplotlib.pyplot as plt
>>> s.plot()
>>> plt.show()
```

```
>>> df2.plot()
>>> plt.show()
```

Data Wrangling with pandas Cheat Sheet

BecomingHuman.AI

Syntax Creating DataFrames

	a	b	c
1	4	7	10
2	5	8	11
3	6	9	12

```
df = pd.DataFrame(  
    {'a': [4, 5, 6],  
     'b': [7, 8, 9],  
     'c': [10, 11, 12]},  
    index = [1, 2, 3])  
Specify values for each column.
```

```
df = pd.DataFrame(  
    [[4, 7, 10],  
     [5, 8, 11],  
     [6, 9, 12]],  
    index = [1, 2, 3],  
    columns = ['a', 'b', 'c'])  
Specify values for each row.
```

		a	b	c
n	v			
d	1	4	7	10
	2	5	8	11
e	2	6	9	12

```
df = pd.DataFrame(  
    {'a': [4, 5, 6],  
     'b': [7, 8, 9],  
     'c': [10, 11, 12]},  
    index = pd.MultiIndex.from_tuples(  
        [(1, 'd'), (2, 'e')],  
        names = ['n', 'v'])  
Create DataFrame with a MultiIndex
```

Method Chaining

Most pandas methods return a DataFrame so that another pandas method can be applied to the result. This improves readability of code.

```
df = (pd.melt(df)  
      .rename(columns={  
          'variable': 'var',  
          'value': 'val'})  
      .query('val >= 200'))
```

Windows

df.expanding()
Return an Expanding object allowing summary functions to be applied cumulatively.

df.rolling(n)
Return a Rolling object allowing summary functions to be applied to windows of length n.

Windows

df.plot.hist()
Histogram for each column



df.plot.scatter(x='w', y='h')
Scatter chart using pairs of points



Tidy Data A foundation for wrangling in pandas

In a tidy data set:

Each variable is saved in its own column

&

Each observation is saved in its own row

Tidy data complements pandas's vectorized operations. pandas will automatically preserve observations as you manipulate variables. No other format works as intuitively with pandas

$M * A$

Reshaping Data Change the layout of a data set

pd.melt(df)
Gather columns into rows.

df.pivot(columns='var', values='val')
Spread rows into columns.

pd.concat([df1, df2])
Append rows of DataFrames

pd.concat([df1, df2], axis=1)
Append columns of DataFrames

df.sort_values('mpg')
Order rows by values of a column (low to high).

df.sort_values('mpg', ascending=False)
Order rows by values of a column (high to low).

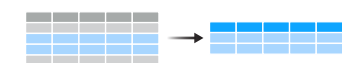
df.rename(columns = {'y': 'year'})
Rename the columns of a DataFrame

df.sort_index()
Sort the index of a DataFrame

df.reset_index()
Reset index of DataFrame to row numbers, moving index to columns.

df.drop(columns=['Length', 'Height'])
Drop columns from DataFrame

Subset Observations (Rows)



df[df.Length > 7]
Extract rows that meet logical criteria.

df.drop_duplicates()
Remove duplicate rows (only considers columns).

df.head(n)
Select first n rows.

df.tail(n)
Select last n rows.

df.sample(frac=0.5)
Randomly select fraction of rows.

df.sample(n=10)
Randomly select n rows.

df.iloc[10:20]
Select rows by position.

df.nlargest(n, 'value')
Select and order top n entries.

df.nsmallest(n, 'value')
Select and order bottom n entries.

Logic in Python (and pandas)

	<	Less than	is	Not equal to
>	>	Greater than	df.column.isin(values)	Group membership
==	==	Equal to	pd.isnull(obj)	Is NaN
<=	<=	Less than or equal to	pd.notnull(obj)	Is not NaN
>=	>=	Greater than or equal to	&[, ~, ^, df.any(), df.all()	Logical and, or, not, xor, any, all

Subset Variables (Columns)



df[['width', 'length', 'species']]
Select multiple columns with specific names.

df['width'] or df.width
Select single column with specific name.

df.filter(regex='regex')
Select columns whose name matches regular expression regex.

Logic in Python (and pandas)	
'.'	Matches strings containing a period '.'
'Length\$'	Matches strings ending with word 'Length'
'^Sepal'	Matches strings beginning with the word 'Sepal'
'^x[1-5]\$'	Matches strings beginning with 'x' and ending with 1,2,3,4,5
'^(?!Species)\$'	Matches strings except the string 'Species'

df.loc[:, 'x2': 'x4']
Select all columns between x2 and x4 (inclusive).

df.iloc[:, [1, 2, 5]]
Select columns in positions 1, 2 and 5 (first column is 0).

df.loc[df['a'] > 10, ['a', 'c']]
Select rows meeting logical condition, and only the specific columns.

Windows



df.groupby(by='col')
Return a GroupBy object, grouped by values in column named 'col'.

df.groupby(level='ind')
Return a GroupBy object, grouped by values in index level named 'ind'.

All of the summary functions listed above can be applied to a group.

size() **agg(function)**
Size of each group. Aggregate group using function.

The examples below can also be applied to groups. In this case, the function is applied on a per-group basis, and the returned vectors are of the length of the original DataFrame.

shift(1)
Copy with values shifted by 1.

rank(method='dense')
Ranks with no gaps.

rank(method='min')
Ranks. Ties get min rank.

rank(pct=True)
Ranks rescaled to interval [0, 1].

rank(method='first')
Ranks. Ties go to first value.

shift(-1)
Copy with values lagged by 1.

cumsum()
Cumulative sum.

cummax()
Cumulative max.

cummin()
Cumulative min.

cumprod()
Cumulative product

Summarise Data

df['w'].value_counts()
Count number of rows with each unique value of variable

len(df)
of rows in DataFrame.

df['w'].nunique()
of distinct values in a column.

df.describe()
Basic descriptive statistics for each column (or GroupBy)



pandas provides a large set of **summary functions** that operate on different kinds of pandas objects (DataFrame columns, Series, GroupBy, Expanding and Rolling (see below)) and produce single values for each of the groups. When applied to a DataFrame, the result is returned as a pandas Series for each column. Examples:

sum()
Sum values of each object.

count()
Count non-NA/null values of each object.

median()
Median value of each object.

quantile([0.25, 0.75])
Quantiles of each object.

apply(function)
Apply function to each object

min()
Minimum value in each object.

max()
Maximum value in each object.

mean()
Mean value of each object.

var()
Variance of each object.

std()
Standard deviation of each object.

Combine Data Sets



Set Operations

pd.merge(ydf, zdf)
Rows that appear in both ydf and zdf (Intersection).

pd.merge(ydf, zdf, how='outer')
Rows that appear in either or both ydf and zdf (Union).

pd.merge(ydf, zdf, how='outer', indicator=True)
.query(' _merge == "left_only"')
.drop(columns=[' _merge'])
Rows that appear in ydf but not zdf (Setdiff)

Handling Missing Data

df.dropna()
Drop rows with any column having NA/null data.

df.fillna(value)

Make New Columns



df.assign(Area=lambda df: df.Length*df.Height)
Compute and append one or more new columns.

df['Volume'] = df.Length*df.Height*df.Depth
Add single column.

pd.qcut(df.col, n, labels=False)
Bin column into n buckets.



pandas provides a large set of vector functions that operate on all columns of a DataFrame or a single selected column (a pandas Series). These functions produce vectors of values for each of the columns, or a single Series for the individual Series. Examples:

max(axis=1)
Element-wise max.

min(axis=1)
Element-wise min.

clip(lower=-10, upper=10)
Trim values at input thresholds

abs()
Absolute value.

Standard Joins

pd.merge(adf, bdf, how='left', on='x1')
Join matching rows from bdf to adf.

pd.merge(adf, bdf, how='right', on='x1')
Join matching rows from adf to bdf.

pd.merge(adf, bdf, how='inner', on='x1')
Join data. Retain only rows in both sets.

pd.merge(adf, bdf, how='outer', on='x1')
Join data. Retain all values, all rows.

Filtering Joins

adf[adf.x1.isin(bdf.x1)]
All rows in adf that have a match in bdf.

adf[~adf.x1.isin(bdf.x1)]
All rows in adf that do not have a match in bdf

Data Wrangling with dplyr and tidyr

Cheat Sheet

Becoming Human.AI

Syntax Helpful conventions for wrangling

dplyr::tbl_df(iris)

Converts data to tbl class. tbl's are easier to examine than data frames. R displays only the data that fits onscreen

```
Source: local data frame [150 x 5]
  Sepal.Length Sepal.Width Petal.Length
1           5.1           3.5           1.4
2           4.9           3.0           1.4
3           4.7           3.2           1.3
4           4.6           3.1           1.5
5           5.0           3.6           1.4
...
Variables not shown: Petal.Width (dbl),
Species (fctr)
```

dplyr::glimpse(iris)

Information dense summary of tbl data.

utils::View(iris)

View data set in spreadsheet-like display (note capital V)

	Sepal.Length	Sepal.Width	Petal.Length	Petal.Width	Species
1	5.1	3.5	1.4	0.2	setosa
2	4.9	3.0	1.4	0.2	setosa
3	4.7	3.2	1.3	0.2	setosa
4	4.6	3.1	1.5	0.2	setosa
5	5.0	3.6	1.4	0.2	setosa
6	5.4	3.9	1.7	0.4	setosa
7	4.6	3.4	1.4	0.3	setosa
8	5.0	3.4	1.5	0.2	setosa

dplyr::%>%

Passes object on left hand side as first argument (or . argument) of function on righthand side.

x %>% f(y) is the same as **f(x, y)**

y %>% f(x, ., z) is the same as **f(x, y, z)**

"Piping" with %>% makes code more readable, e.g.

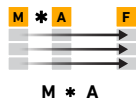
```
iris %>%
  group_by(Species) %>%
  summarise(avg = mean(Sepal.Width)) %>%
  arrange(avg)
```

Tidy Data A foundation for wrangling in R

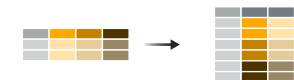
In a tidy data set:



Tidy data complements R's vectorized operations. R will automatically preserve observations as you manipulate variables. No other format works as intuitively with R



Reshaping Data Change the layout of a data set



tidyr::gather(cases, "year", "n", 2:4)
Gather columns into rows.



tidyr::spread(pollution, size, amount)
Spread rows into columns



tidyr::separate(storms, date, c("y", "m", "d"))
separate(storms, date, c("y", "m", "d"))



tidyr::unite(data, col, ..., sep)
Unite several columns into one.

dplyr::data_frame(a = 1:3, b = 4:6)
Combine vectors into data frame (optimized).

dplyr::arrange(mtcars, mpg)
Order rows by values of a column (low to high).

dplyr::arrange(mtcars, desc(mpg))
Order rows by values of a column (high to low).

dplyr::rename(tb, y = year)
Rename the columns of a data frame.

Subset Observations (Rows)



dplyr::filter(iris, Sepal.Length > 7)
Extract rows that meet logical criteria.

dplyr::distinct(iris)
Remove duplicate rows.

dplyr::sample_frac(iris, 0.5, replace = TRUE)
Randomly select fraction of rows.

dplyr::sample_n(iris, 10, replace = TRUE)
Randomly select n rows.

dplyr::slice(iris, 10:15)
Select rows by position.

dplyr::top_n(storms, 2, date)
Select and order top n entries (by group if grouped data).

Subset Variables (Columns)



dplyr::select(iris, Sepal.Width, Petal.Length, Species)
Select columns by name or helper function.

Helper functions for select - ?select

select(iris, contains(" "))
Select columns whose name contains a character string.

select(iris, ends_with("Length"))
Select columns whose name ends with a character string.

select(iris, everything())
Select every column.

select(iris, matches("1.1"))
Select columns whose name matches a regular expression.

select(iris, num_range("x", 1:5))
Select columns named x1, x2, x3, x4, x5.

select(iris, one_of(c("Species", "Genus")))
Select columns whose names are in a group of names.

select(iris, starts_with("Sepal"))
Select columns whose name starts with a character string.

select(iris, Sepal.Length:Petal.Width)
Select all columns between Sepal.Length and Petal.Width (inclusive).

select(iris, -Species)
Select all columns except Species.

Group Data

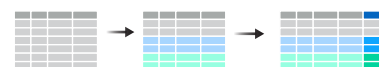
dplyr::group_by(iris, Species)
Group data into rows with the same value of Species.

dplyr::ungroup(iris)
Remove grouping information from data frame.

iris %>% group_by(Species) %>% summarise(...)
Compute separate summary row for each group.



iris %>% group_by(Species) %>% mutate(...)
Compute new variables by group.



Summarise Data



dplyr::summarise(iris, avg = mean(Sepal.Length))
Summarise data into single row of values.

dplyr::summarise_each(iris, funs(mean))
Apply summary function to each column.

dplyr::count(iris, Species, wt = Sepal.Length)
Count number of rows with each unique value of variable (with or without weights).



Summarise uses **summary functions**, functions that take a vector of values and return a single value, such as:

dplyr::first
First value of a vector.

dplyr::last
Last value of a vector.

dplyr::nth
Nth value of a vector.

dplyr::n
of values in a vector.

dplyr::n_distinct
of distinct values in a vector.

IQR
IQR of a vector

min
Minimum value in a vector.

max
Maximum value in a vector.

mean
Mean value of a vector.

median
Median value of a vector.

var
Variance of a vector.

sd
Standard deviation of a vector.

Combine Data Sets



Mutating Joins

dplyr::left_join(a, b, by = "x1")
Join matching rows from b to a.

dplyr::right_join(a, b, by = "x1")
Join matching rows from a to b.

dplyr::inner_join(a, b, by = "x1")
Join data. Retain only rows in both sets.

dplyr::full_join(a, b, by = "x1")
Join data. Retain all values, all rows.

Filtering Joins

dplyr::semi_join(a, b, by = "x1")
All rows in a that have a match in b.

dplyr::anti_join(a, b, by = "x1")
All rows in a that do not have a match in b

Make New Variables



dplyr::mutate(iris, sepal = Sepal.Length + Sepal.Width)
Compute and append one or more new columns.

dplyr::mutate_each(iris, funs(min_rank))
Apply window function to each column.

dplyr::transmute(iris, sepal = Sepal.Length + Sepal.Width)
Compute one or more new columns. Drop original columns



Mutate uses **window functions**, functions that take a vector of values and return another vector of values, such as:

dplyr::lead
Copy with values shifted by 1.

dplyr::lag
Copy with values lagged by 1.

dplyr::dense_rank
Ranks with no gaps.

dplyr::min_rank
Ranks. Ties get min rank.

dplyr::percent_rank
Ranks rescaled to [0, 1].

dplyr::row_number
Ranks. Ties got to first value.

dplyr::ntile
Bin vector into n buckets.

dplyr::between
Are values between a and b?

dplyr::cume_dist
Cumulative distribution.

dplyr::cumall
Cumulative all

dplyr::cumany
Cumulative any

dplyr::cummean
Cumulative mean

cumsum
Cumulative sum

cummax
Cumulative max

cummin
Cumulative min

cumprod
Cumulative prod

pmax
Element-wise max

pmin
Element-wise min

Set Operations

dplyr::intersect(y, z)
Rows that appear in both y and z.

dplyr::union(y, z)
Rows that appear in either or both y and z.

dplyr::setdiff(y, z)
Rows that appear in y but not z.

Binding

dplyr::bind_rows(y, z)
Append z to y as new rows.

dplyr::bind_cols(y, z)
Append z to y as new columns. Caution: matches rows by position.

The SciPy library is one of the core packages for scientific computing that provides mathematical algorithms and convenience functions built on the NumPy extension of Python.

SciPy Linear Algebra Cheat Sheet

Becoming Human.AI



Interacting With NumPy

Also see NumPy

```
>>> import numpy as np
>>> a = np.array([1,2,3])
>>> b = np.array([(1+5j,2,3j), (4j,5j,6j)])
>>> c = np.array([[(1,5,2,3), (4,5,6)], [(3,2,1), (4,5,6)]])
```

Index Tricks

```
>>> np.mgrid[0:5,0:5]           Create a dense meshgrid
>>> np.ogrid[0:2,0:2]           Create an open meshgrid
>>> np.r_[3,0]*5,-1:1:10j]       Stack arrays vertically (row-wise)
>>> np.c_[b,c]                   Create stacked column-wise arrays
```

Shape Manipulation

```
>>> np.transpose(b)              Permute array dimensions
>>> b.flatten()                  Flatten the array
>>> np.hstack((b,c))             Stack arrays horizontally (column-wise)
>>> np.vstack((a,b))             Stack arrays vertically (row-wise)
>>> np.hsplit(c,2)               Split the array horizontally at the 2nd index
>>> np.vsplit(d,2)               Split the array vertically at the 2nd index
```

Polynomials

```
>>> from numpy import poly1d
>>> p = poly1d([3,4,5])         Create a polynomial object
```

Vectorizing Functions

```
>>> def myfunc(a):
    if a < 0:
        return a*2
    else:
        return a/2
>>> np.vectorize(myfunc)        Vectorize functions
```

Type Handling

```
>>> np.real(b)                  Return the real part of the array elements
>>> np.imag(b)>>>               Return the imaginary part of the array elements
np.real_if_close(c,tol=1000)    Return a real array if complex parts close to 0
>>> np.cast['f'](np.pi)        Cast object to a data type
```

Other Useful Functions

```
>>> np.angle(b,deg=True)        Return the angle of the complex argumen
>>> g = np.linspace(0,np.pi,num=5) Create an array of evenly spaced values
>>> g[3:] += np.pi              (number of samples)
>>> np.unwrap(g)                 Unwrap
>>> np.logspace(0,10,3)          Create an array of evenly spaced values (log scale)
>>> np.select([c<4],[c**2])      Return values from a list of arrays
                                   depending on conditions
>>> misc.factorial(a)            Factorial
>>> misc.comb(10,3,exact=True)   Combine N things taken at k time
>>> misc.central_diff_weights(3) Weights for Np-point central derivative
>>> misc.derivative(myfunc,1.0) Find the n-th derivative of a function at a point
```

Linear Algebra

Also see NumPy

You'll use the linalg and sparse modules. Note that scipy.linalg contains and expands on numpy.linalg

```
>>> from scipy import linalg, sparse
```

Creating Matrices

```
>>> A = np.matrix(np.random.random((2,2)))
>>> B = np.asmatrix(b)
>>> C = np.mat(np.random.random((10,5)))
>>> D = np.mat([[3,4], [5,6]])
```

Basic Matrix Routines

```
Inverse
>>> A.I                          Inverse
>>> linalg.inv(A)               Inverse
```

```
Transposition
>>> A.T                          Transpose matrix
>>> A.H                          Conjugate transposition
```

```
Trace
>>> np.trace(A)                  Trace
```

```
Norm
>>> linalg.norm(A)              Frobenius norm
>>> linalg.norm                 L1 norm (max column sum)
>>> linalg.norm(A,np.inf)       L inf norm (max row sum)
```

```
Rank
>>> np.linalg.matrix_rank(C)     Matrix rank
```

```
Determinant
>>> linalg.det(A)                Determinant
```

```
Solving linear problems
>>> linalg.solve(A,b)            Solver for dense matrices
>>> E = np.mat(A).T              Solver for dense matrices
>>> linalg.lstsq(F,E)            Least-squares solution to linear matrix
```

```
Generalized inverse
>>> linalg.pinv(C)               Compute the pseudo-inverse of a matrix
                                   (least-squares solver)
>>> linalg.pinv2(C)              Compute the pseudo-inverse of
                                   a matrix (SVD)
```

Creating Matrices

```
>>> F = np.eye(3, k=1)           Create a 2X2 identity matrix
>>> G = np.mat(np.identity(2))   Create a 2x2 identity matrix
>>> C[C > 0.5] = 0
>>> H = sparse.csr_matrix(C)      Compressed Sparse Row matrix
>>> I = sparse.csc_matrix(D)      Compressed Sparse Column matrix
>>> J = sparse.dok_matrix(A)      Dictionary Of Keys matrix
>>> E.todense()                  Sparse matrix to full matrix
>>> sparse.isspmatrix_csc(A)      Identify sparse matrix
```

Matrix Functions

```
Addition
>>> np.add(A,D)                  Addition
```

```
Subtraction
>>> np.subtract(A,D)             Subtraction
```

```
Division
>>> np.divide(A,D)               Division
```

```
Multiplication
>>> A @ D                        Multiplication operator (Python 3)
>>> np.multiply(D,A)            Multiplication
>>> np.dot(A,D)                 Dot product
>>> np.vdot(A,D)                Vector dot product
>>> np.inner(A,D)               Inner product
>>> np.outer(A,D)               Outer product
>>> np.tensordot(A,D)           Tensor dot product
>>> np.kron(A,D)                Kronecker product
```

```
Exponential Functions
>>> linalg.expm(A)               Matrix exponential
>>> linalg.expm2(A)              Matrix exponential (Taylor Series)
>>> linalg.expm3(D)              Matrix exponential
                                   (eigenvalue decomposition)
```

```
Logarithm Function
>>> linalg.logm(A)               Matrix logarithm
```

```
Trigonometric Functions
>>> linalg.sinm(D)               Matrix sine
>>> linalg.cosm(D)               Matrix cosine
>>> linalg.tanm(A)               Matrix tangent
```

```
Hyperbolic Trigonometric Functions
>>> linalg.sinhm(D)              Hyperbolic matrix sine
>>> linalg.coshm(D)              Hyperbolic matrix cosine
>>> linalg.tanhm(A)              Hyperbolic matrix tangent
```

```
Matrix Sign Function
>>> np.signm(A)                  Matrix sign function
```

```
Matrix Square Root
>>> linalg.sqrtm(A)              Matrix square root
```

```
Arbitrary Functions
>>> linalg.funm(A, lambda x: x*x) Evaluate matrix function
```

Sparse Matrix Routines

```
Inverse
>>> sparse.linalg.inv(l)         Inverse
```

```
Norm
>>> sparse.linalg.norm(l)        Norm
```

```
Solving linear problems
>>> sparse.linalg.spsolve(H,l)   Solver for sparse matrices
```

Sparse Matrix Functions

```
>>> sparse.linalg.expm(l)        Sparse matrix exponential
```

Decompositions

Eigenvalues and Eigenvectors

```
>>> la, v = linalg.eig(A)        Solve ordinary or generalized
                                   eigenvalue problem for
                                   square matrix
>>> l1, l2 = la
>>> v[:,0]                       First eigenvector
>>> v[:,1]                       Second eigenvector
>>> linalg.eigvals(A)             Unpack eigenvalues
```

Singular Value Decomposition

```
>>> U,s,Vh = linalg.svd(B)        Singular Value Decomposition (SVD)
>>> M,N = B.shape
>>> Sig = linalg.diagsvd(s,M,N)    Construct sigma matrix in SVD
```

LU Decomposition

```
>>> P,L,U = linalg.lu(C)           LU Decomposition
```

Sparse Matrix Decompositions

```
>>> la, v = sparse.linalg.eigs(F,1) Eigenvalues and eigenvectors
>>> sparse.linalg.svds(H, 2)        SVD
```

Asking For Help

```
>>> help(scipy.linalg.diagsvd)
>>> np.info(np.matrix)
```

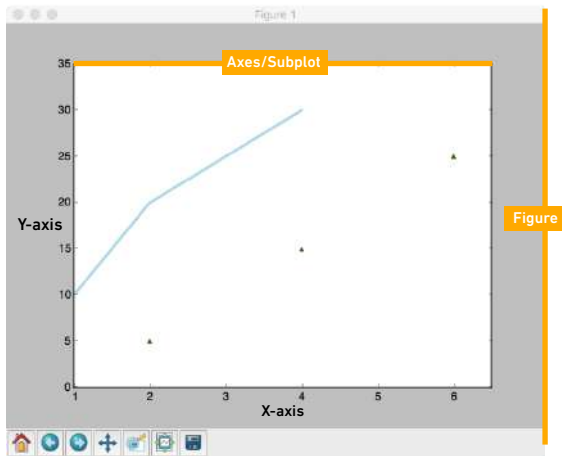
Matplotlib is a Python 2D plotting library which produces publication-quality figures in a variety of hardcopy formats and interactive environments across platforms.

Matplotlib Cheat Sheet

BecomingHuman.AI

Anatomy & Workflow

Plot Anatomy



Workflow

- 01 Prepare data
- 02 Create plot
- 03 Plot
- 04 Customize plot
- 05 Save plot
- 06 Show plot

```
>>> import matplotlib.pyplot as plt
>>> x = [1,2,3,4]
>>> y = [10,20,25,30]
>>> fig = plt.figure()
>>> ax = fig.add_subplot(111)
>>> ax.plot(x, y, color='lightblue', linewidth=3)
>>> ax.scatter([2,4,6],
>>>            [5,15,25],
>>>            color='darkgreen',
>>>            marker='^')
>>> ax.set_xlim(1, 6.5)
>>> plt.savefig('foo.png')
>>> plt.show()
```

Prepare The Data

Also see Lists & NumPy

Index Tricks

```
>>> import numpy as np
>>> x = np.linspace(0, 10, 100)
>>> y = np.cos(x)
>>> z = np.sin(x)

>>> data = 2 * np.random.random((10, 10))
>>> data2 = 3 * np.random.random((10, 10))
>>> Y, X = np.mgrid[-3:3:100j, -3:3:100j]
>>> U = -1 - X**2 + Y
>>> V = 1 + X - Y**2
>>> from matplotlib.cbook import get_sample_data
>>> img = np.load(get_sample_data('axes_grid/bivariate_normal.npy'))
```

Create Plot

```
>>> import matplotlib.pyplot as plt

>>> fig = plt.figure()
>>> fig2 = plt.figure(figsize=plt.figaspect(2.0))

>>> fig.add_axes()
>>> ax1 = fig.add_subplot(221) # row-col-num
>>> ax3 = fig.add_subplot(212)
>>> fig3, axes = plt.subplots(nrows=2,ncols=2)
>>> fig4, axes2 = plt.subplots(ncols=3)
```

Plotting Routines

1D Data

```
>>> lines = ax.plot(x,y)
>>> ax.scatter(x,y)
>>> axes[0,0].bar([1,2,3],[3,4,5])
>>> axes[1,0].barh([0.5,1,2.5],[0,1,2])
>>> axes[1,1].axhline(0.45)
>>> axes[0,1].axvline(0.65)
>>> ax.fill(x,y,color='blue')
>>> ax.fill_between(x,y,color='yellow')

2D Data
```

```
>>> fig, ax = plt.subplots()
>>> im = ax.imshow(img,
>>>                arrays cmap='gist_earth',
>>>                interpolation='nearest',
>>>                vmin=-2,
>>>                vmax=2)
```

Customize Plot

Colors, Color Bars & Color Maps

```
>>> plt.plot(x, x, x**2, x, x**3)
>>> ax.plot(x, y, alpha = 0.4)
>>> ax.plot(x, y, c='k')
>>> fig.colorbar(im, orientation='horizontal')
>>> im = ax.imshow(img,
>>>                cmap='seismic')
```

Markers

```
>>> fig, ax = plt.subplots()
>>> ax.scatter(x,y,marker='')
>>> ax.plot(x,y,marker='o')
```

Linestyles

```
>>> plt.plot(x,y,linewidth=4.0)
>>> plt.plot(x,y,ls='solid')
>>> plt.plot(x,y,ls='--')
>>> plt.plot(x,y,--,'x'*2,y**2,--')
>>> plt.setp(lines,color='r',linewidth=4.0)
```

Text & Annotations

```
>>> ax.text(1,
>>>         -2.1, 'Example Graph',
>>>         style='italic')
>>> ax.annotate('Sine', xy=(8, 0),
>>>             xycoords='data',
>>>             xytext=(10.5, 0),
>>>             textcoords='data',
>>>             arrowprops=dict(arrowstyle="->",
>>>                             connectionstyle="arc3"))
```

Mathtext

```
>>> plt.title(r'$\sigma_i=15$', fontsize=20)
```

Limits, Legends & Layouts

Limits & Autoscaling

```
>>> ax.margins(x=0.0,y=0.1)
>>> ax.axis('equal')
>>> ax.set(xlim=[0,10.5],ylim=[-1.5,1.5])
>>> ax.set_xlim(0,10.5)
```

Legends

```
>>> ax.set(title='An Example Axes',
>>>         ylabel='Y-Axis',
>>>         xlabel='X-Axis')
>>> ax.legend(loc='best')
```

Ticks

```
>>> ax.xaxis.set(ticks=range(1,5),
>>>              ticklabels=[3,100,-12,'foo'])
>>> ax.yaxis.set(direction='inout',
>>>              length=10)
```

Subplot Spacing

```
>>> fig3.subplots_adjust(wspace=0.5,
>>>                      hspace=0.3,
>>>                      left=0.125,
>>>                      right=0.9,
>>>                      top=0.9,
>>>                      bottom=0.1)
```

Axes Spines

```
>>> ax1.spines['top'].set_visible(False)
>>> ax1.spines['bottom'].set_position(('outward',10))
```

Save Plot

Save figures

```
>>> plt.savefig('foo.png')
>>> plt.savefig('foo.png', transparent=True)
```

Show Plot

```
>>> plt.show()
```

Close & Clear

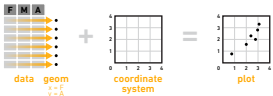
```
>>> plt.cla()
>>> plt.clf()
>>> plt.close()
```


Data Visualisation with ggplot2

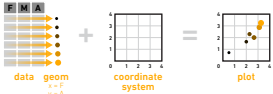
Cheat Sheet

Basics

ggplot2 is based on the **grammar of graphics**, the idea that you can build every graph from the same few components: a data set, a set of **geoms**—visual marks that represent data points, and a **coordinate system**.



To display data values, map variables in the data set to aesthetic properties of the geom like **size**, **color**, and **x** and **y** locations



Build a graph with **qplot()** or **ggplot()**

aesthetic mappings **data** **geom**

qplot(x = cty, y = hwy, color = cyl, data = mpg, geom = "point")
Creates a complete plot with given data, geom, and mappings. Supplies many useful defaults.

ggplot(data = mpg, aes(x = cty, y = hwy))

Begin a plot that you finish by adding layers to. No defaults, but provides more control than qplot().

data **add layers, elements with +**

geom_point(aes(color = cyl)) +
geom_smooth(method = "lm") +
coord_cartesian() +
scale_color_gradient() +
theme_bw()

additional elements

Add a new layer to a plot with a **geom_***() or **stat_***() function. Each provides a geom, a set of aesthetic mappings, and a default stat and position adjustment.

last_plot()

Returns the last plot

ggsave("plot.png", width = 5, height = 5)

Saves last plot as 5" x 5" file named "plot.png" in working directory. Matches file type to file extension.

Coordinate Systems

r <- b + geo_m_bar()

r <- coord_cartesian(xlim = c(0, 5))
xlim, ylim
The default cartesian coordinate system

r <- coord_fixed(ratio = 1/2)
ratio, xlim, ylim
Cartesian coordinates with fixed aspect ratio between x and y units

r <- coord_flip()
xlim, ylim
Flipped Cartesian coordinates

r <- coord_polar(theta = "x", direction = 1)
theta, start, direction
Polar coordinates

r <- coord_trans(trans = "sqrt")
strans, ylims, xlims, lims
Transformed cartesian coordinates. Set extras and strains to the name of a window function.

r <- coord_map(projection = "ortho", orientation = c(41, -74, 0))
projection, orientation, xlim, ylim
Map projections from the maptools package (mercator (default), azequialera, lagrange, etc.)

Geoms

Use a geom to represent data points, use the geom's aesthetic properties to represent variables. Each function returns a layer

One Variable

Continuous

a <- geom_area(stat = "bin")
x, y, alpha, color, fill, linetype, size
b = geom_area(aes(y = ..density..), stat = "bin")

a <- geom_density(kernel = "gaussian")
x, y, alpha, color, fill, linetype, size, weight
b = geom_density(aes(y = ..density..))

a <- geom_dotplot()

x, y, alpha, color, fill

a <- geom_histogram(binwidth = 5)

x, y, alpha, color, fill, linetype, size, weight
b = geom_histogram(aes(y = ..density..))

Discrete

b <- geom_bar(aes(fill))

x, alpha, color, fill, linetype, size, weight

Graphical Primitives

c <- geom_polygon(aes(group = group))

x, y, alpha, color, fill, linetype, size

d <- ggplot(economics, aes(date, unemployment))

e <- geom_path(linetype = "dotted", linejoin = "round", linemitre = 1)

x, y, alpha, color, linetype, size

d <- geom_ribbon(aes(ymin = unemployment - 900, ymax = unemployment + 900))

x, y, alpha, color, fill, linetype, size

d <- geom_segment(aes(xend = long + delta, long, yend = lat + delta, lat))

x, y, alpha, color, fill, linetype, size

e <- geom_rect(aes(xmin = long, ymin = lat, xmax = long + delta, long, ymax = lat + delta, lat))

x, y, alpha, color, fill, linetype, size

m <- ggplot(seals, aes(long, lat))

m <- geom_contour(aes(z = z))

x, y, z, alpha, color, linetype, size, weight

m <- geom_raster(aes(fill = z), hjust = 0.5, vjust = 0.5, interpolate = FALSE)

x, y, alpha, fill

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

m <- geom_tile(aes(fill = z))

x, y, alpha, color, fill, linetype, size

Two Variables

Continuous X, Continuous Y

f <- geom_blank()

x, y, alpha, color, fill, shape, size

f <- geom_jitter

x, y, alpha, color, fill, shape, size

f <- geom_point

x, y, alpha, color, fill, shape, size

f <- geom_quantile

x, y, alpha, color, fill, shape, size

f <- geom_rug(sides = "b")

x, y, alpha, color, fill, shape, size

f <- geom_smooth(model = "lm")

x, y, alpha, color, fill, shape, size

f <- geom_text(aes(label = cty))

x, y, alpha, color, fill, shape, size

f <- geom_text(aes(label = cty))

x, y, alpha, color, fill, shape, size

f <- geom_text(aes(label = cty))

x, y, alpha, color, fill, shape, size

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x, y, alpha, color, fill, shape, size

f <- geom_text(aes(label = cty))

x, y, alpha, color, fill, shape, size

f <- geom_text(aes(label = cty))

x, y, alpha, color, fill, shape, size

Continuous Bivariate Distribution

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

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x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

i <- geom_bin2d(binwidth = c(5, 0.5))

x, y, alpha, color, fill, linetype, size

Continuous Function

j <- ggplot(economics, aes(date, unemployment))

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x, y, alpha, color, fill, linetype, size

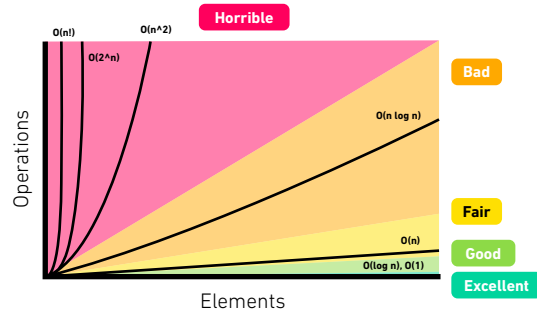
j <- geom_area

x, y, alpha, color, fill, linetype, size

j <- geom_area

x,

Big-O Complexity Chart



Data Structure Operation

	Time Complexity				Space Complexity			
	Average		Worst		Worst			
	Access	Search	Insertion	Deletion	Access	Search	Insertion	Deletion
Array	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$
Stack	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$
Queue	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$
Singly-Linked List	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$
Doubly-Linked List	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$	$\Theta(n)$	$\Theta(n)$	$\Theta(1)$	$\Theta(1)$
Skip List	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n \log(n))$
Hash Table	N/A	$\Theta(1)$	$\Theta(1)$	$\Theta(1)$	N/A	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$
Binary Search Tree	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$
Cartesian Tree	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	N/A	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$
B-Tree	N/A	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$
Red-Black Tree	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$
Splay Tree	N/A	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	N/A	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$
AVL Tree	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$
KD Tree	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$	$\Theta(n)$

Array Sorting Algorithms

	Time Complexity			Space Complexity
	Best	Average	Worst	Worst
Quicksort	$\Omega(n \log(n))$	$\Theta(n \log(n))$	$O(n^2)$	$O(n \log(n))$
Mergesort	$\Omega(n \log(n))$	$\Theta(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$
Timsort	$\Omega(n)$	$\Theta(n \log(n))$	$O(n \log(n))$	$\Theta(n)$
Heapsort	$\Omega(n \log(n))$	$\Theta(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$
Bubble Sort	$\Omega(n)$	$\Theta(n^2)$	$O(n^2)$	$\Theta(n)$
Insertion Sort	$\Omega(n)$	$\Theta(n^2)$	$O(n^2)$	$\Theta(n)$
Selection Sort	$\Omega(n^2)$	$\Theta(n^2)$	$O(n^2)$	$\Omega(n^2)$
Tree Sort	$\Omega(n \log(n))$	$\Theta(n \log(n))$	$O(n^2)$	$O(n \log(n))$
Shell Sort	$\Omega(n \log(n))$	$\Theta(n(\log(n))^2)$	$O(n(\log(n))^2)$	$O(n \log(n))$
Bucket Sort	$\Omega(n+k)$	$\Theta(n+k)$	$O(n^2)$	$\Omega(n+k)$
Radix Sort	$\Omega(n+k)$	$\Theta(n+k)$	$\Omega(n+k)$	$\Omega(n+k)$
Counting Sort	$\Omega(n+k)$	$\Theta(n+k)$	$\Omega(n+k)$	$\Omega(n+k)$
Cubesort	$\Omega(n)$	$\Theta(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$