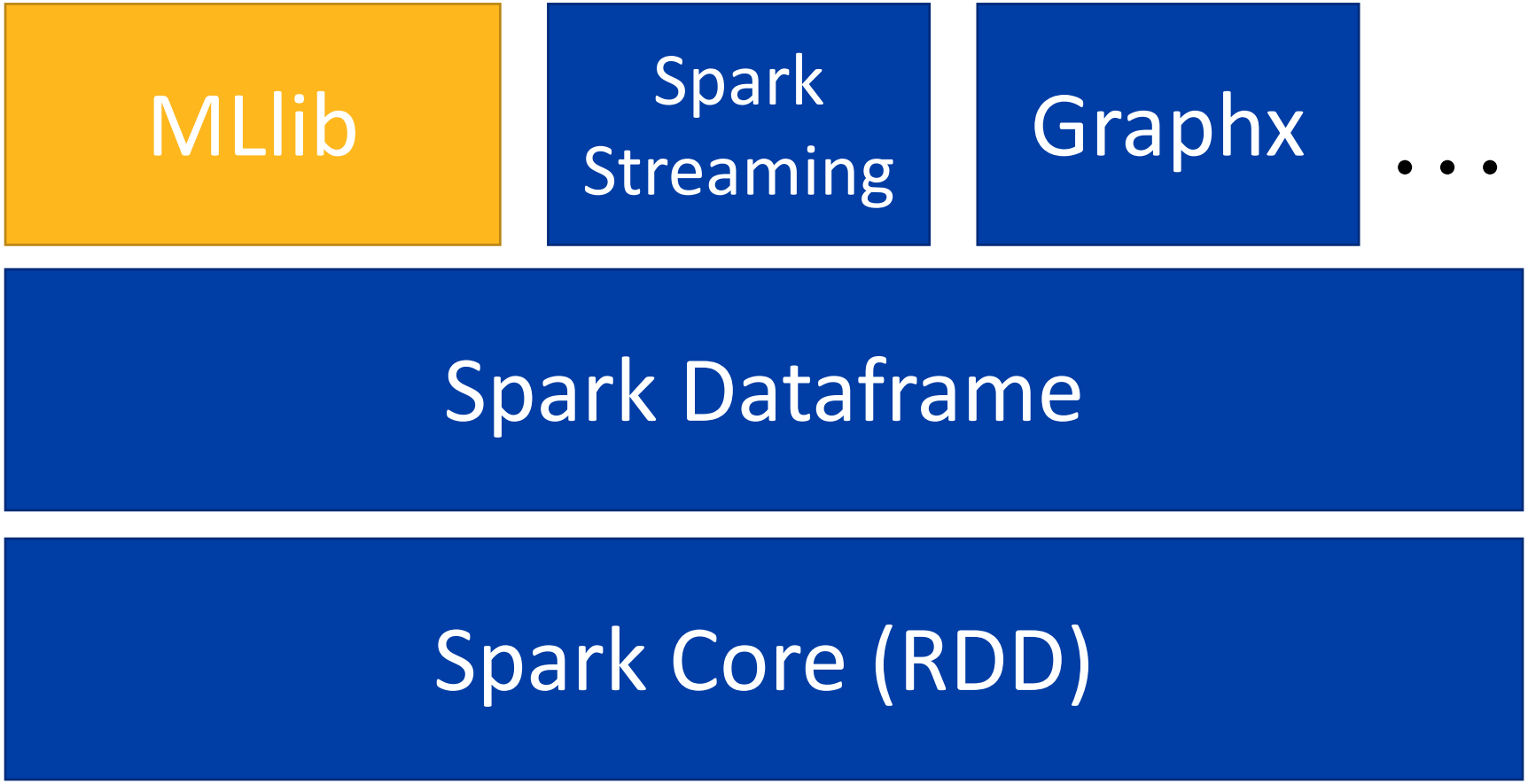
Big Data Meets Machine Learning

Apache Spark MLlib

MLlib


MLlib
Spark Streaming
Graphx
. . .
Spark Dataframe
Spark Core (RDD)

Machine Learning Algorithms

- Supervised learning
  - Given a set of features and labels
  - Builds a model that predicts the label from the features
  - E.g., classification and regression
- Unsupervised learning
  - Given a set of features without labels
  - Finds interesting patterns or underlying structure
  - E.g., clustering and association mining

Overview of MLlib

- Simple primitives
- Basic Statistics
- Extractors, transformations
- Estimators
- Evaluators
- Model tuning

spark.mllib Vs spark.ml

- spark.mllib
  - RDD-based library which is now in maintenance mode
  - Will be deprecated in Spark 3.x
  - Not recommended to use
- spark.ml
  - Dataframe-based API
  - Recommended
  - Replaces (almost) everything in the RDD-API
- Be aware when searching online on which API is used

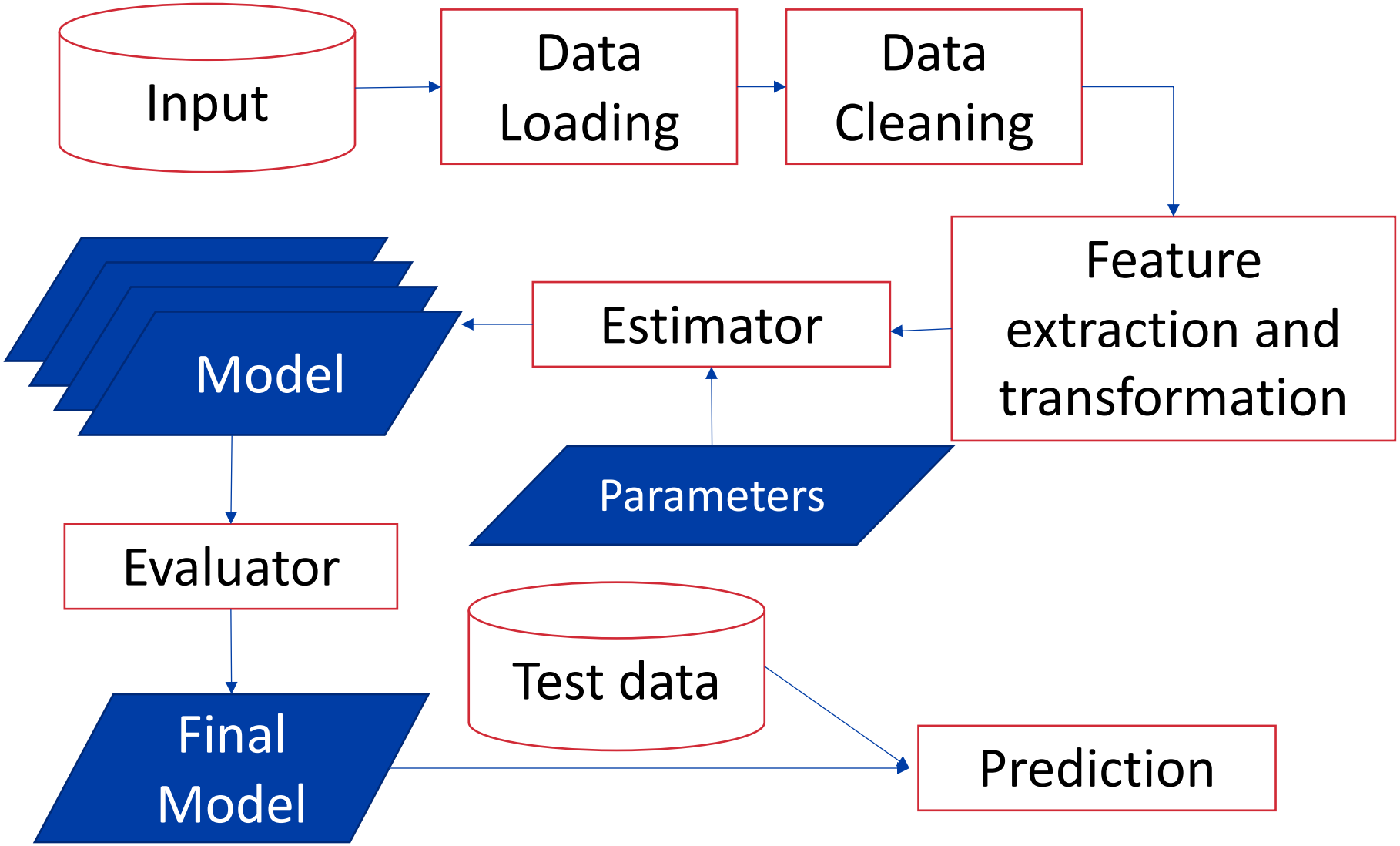
Simple Primitives

- Local Vector (Data Type)
  - To represent features
  - Example: (1.2, 0.0, 0.0, 3.4)
  - Dense vector [1.2, 0.0, 0.0, 3.4]
  - Sparse vector [0, 3], [1.2, 3.4]
- Local Matrix (Data Type)
  - Dense and Sparse
- Dataframe.randomSplit
  - Randomly splits an input dataset
  - Helps in building training and test sets

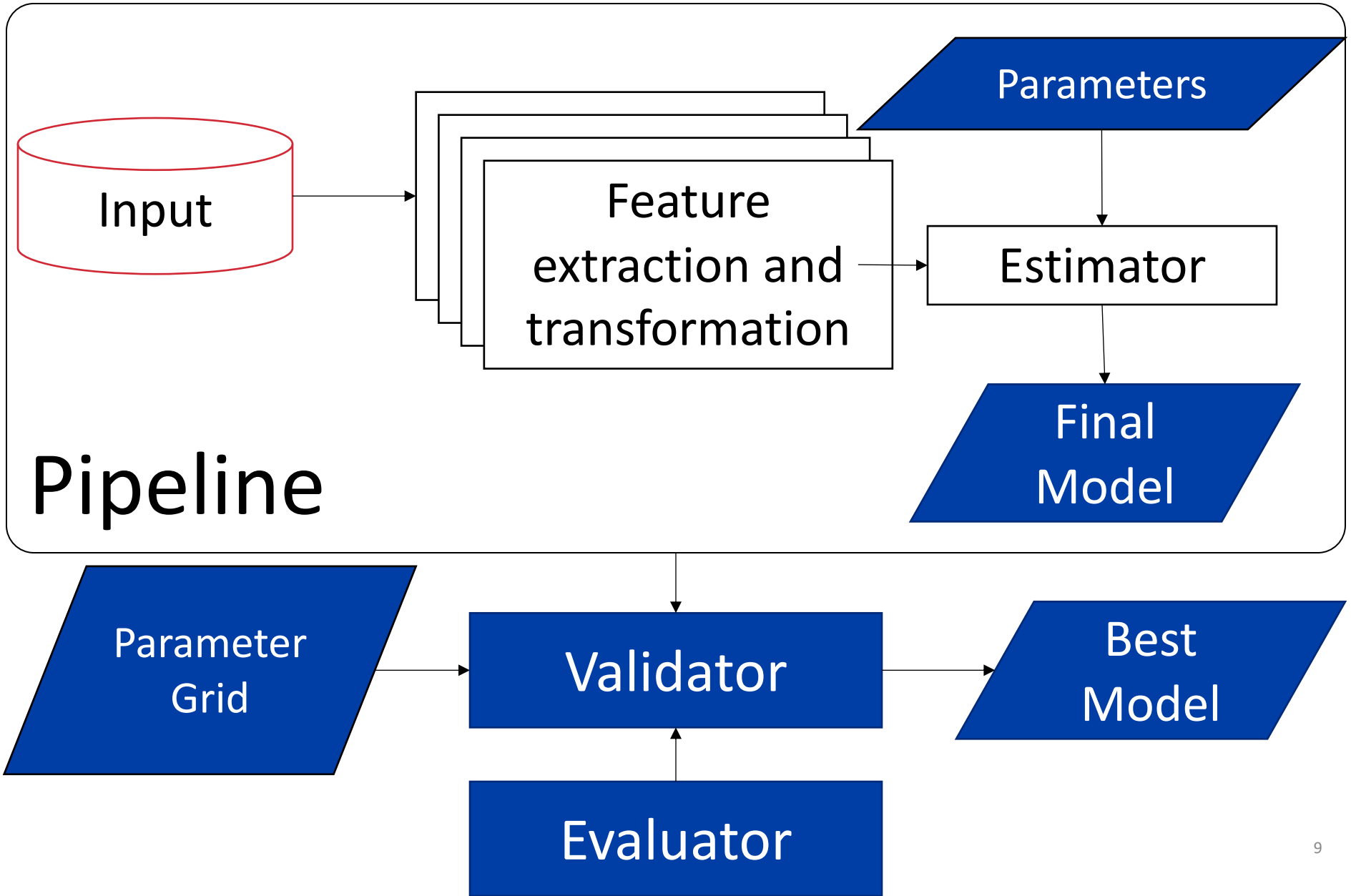
Basic Statistics

- Column statistics
  - Minimum, Maximum, count, … etc.
- Correlation
  - Pearson's and Spearman's correlation
- Hypothesis testing
  - Chi-square Test χ^2

ML Stages


Input
Data Loading
Data Cleaning
Feature extraction and transformation
Estimator
Model
Parameters
Evaluator
Test data
Final Model
Prediction

ML Pipeline


Parameters
Input
Feature extraction and transformation
Estimator
Final Model
Pipeline
Parameter Grid
Validator
Best Model
Evaluator

Transformations

- Used in feature extraction, dimensionality reduction, or schema transformation
- Text transformations
- Encoding
- Normalization
- Hashing

TF-IDF

- Term Frequency-Inverse Document Frequency
- A measure of the importance of a term in a document
- TF: Count of a term in a document
- DF: Number of documents that contain a term
- $IDF(t, D) = \log \frac{|D|+1}{DF(t,D)+1}$
- $TFIDF(t, D) = TF(t, d) \cdot IDF(t, D)$
- Classes: HashingTF, CountVectorizer

Word2Vec

- Converts each sequence of words to a fixed-size vector
- Similar sequences of words are supposed to be mapped to nearby vectors using this model

Other Text Transformers

- Tokenizer: Extracts words (tokens) from text
- StopWordRemover: Removes common words, e.g., a, the, an
- *n*-gram: Given a sequence of words, it generates subsequences of length n
- StringIndexer: Converts each unique string, e.g., label or class, to a numeric value
- IndexToString: Converts each integer value to a String value using a lookup table

Encoders

- PCA (Principal Component Analysis)
  - Reduces number of dimensions to a set of uncorrelated dimensions (components)
- DiscreteCosineTransform (DCT)
  - Frequency analysis
- OneHotEncoder: Converts categorical values to a vector with one bit set for the category

Numeric Transformers

- Binarizer: Converts numerical values to (0/1) based on a threshold
- Bucketizer: Converts continuous values to a set of n+1 buckets based on n thresholds
- QuantileDiscretizer: Places numeric values into buckets based on quantiles
- Normalizer: normalizes each vector to have unit norm. For example,

$$[4.0 \quad 10.0 \quad 2.0]$$
$$\rightarrow [0.25 \quad 0.625 \quad 0.125]$$

- MinMaxScaler: Scales each feature in a vector to a standard scale, e.g., [0.0, 1.0]

Other Transformers

- Imputer: Replaces missing values by a number or the mean
- VectorAssembler: Combines multiple attributes into a vector attribute
- VectorSlicer: Extracts a subarray of a long vector
- SQLTransformer: Applies an SQL query on the input dataset

Applying Transformers

- Simple transformers
  - Can be applied by looking at each individual record
  - E.g., `Bucketizer`, or `VectorAssembler`
  - Applied by calling the `transform` method
  - E.g., `outdf = model.transform(indf)`
- Holistic transformers
  - Need to see the entire dataset first before they can work
  - e.g., `MinMaxScaler`, `HashingTF`, `StringIndexer`
  - To apply them, you need to call `fit` then `transform`
  - e.g., `outdf = model.fit(indf).transform(indf)`

Estimators

- An estimator is a machine learning algorithm that fits a model on the data
- Classification
  - Classifies data points into discrete points (categories)
- Regression
  - Estimates a continuous numeric
- Clustering
  - Groups similar records together into clusters
- Collaborative filtering (Recommendation)
  - Predicts (missing) user ratings for items
- Frequent Pattern Mining

Classification and regression

- Supervised learning algorithms
- Classification
  - Logistic regression
  - Decision tree
  - Naïve Bayes
  - …
- Regression
  - Linear regression
  - Decision tree regression
  - Random forest regression
  - …

Clustering

- Unsupervised learning method
- K-means clustering. Clustering based on distance between vectors
- Latent Dirichlet allocation (LDA). Groups vectors based on some latent (hidden) variables
- Bisecting k-means. Hierarchical clustering
- Gaussian Mixture Model (GMM). Breaks down data distribution into multiple Gaussian distributions

Evaluators

- An Evaluator takes a model and produces numeric values that measure the goodness of the model for a specific dataset
- BinaryClassificationEvaluator evaluates binary classifiers using precision, recall, F-measure, area under ROC curve, … etc.
- MulticlassClassificationEvaluator evaluates multiclass classifiers using confusion matrix, accuracy, precision, recall … etc.

Evaluators

- ClusteringEvaluator evaluates clustering algorithms using sum of squared distances
- RegressionEvaluator evaluates regression models using Mean Squared Error (MSE), Root Mean Squared Error (RMSE) … etc.

Validators

- Each model has its own parameters that are usually no intuitive to tune
- A validator takes a pipeline, an evaluator, and a set of parameters and it tries all possible combinations of parameters to find the best model, i.e., the model that gives the best numeric evaluation metric
- Examples, CrossValidator and TrainValidationSplit

Further Reading

- Documentation
  - http://spark.apache.org/docs/latest/ml-guide.html
- MLlib paper
  - X. Meng et al, “MLlib: Machine Learning in Apache Spark”, Journal of Machine Learning Research 17:34:1-34:7 (2016)