ML with Spark

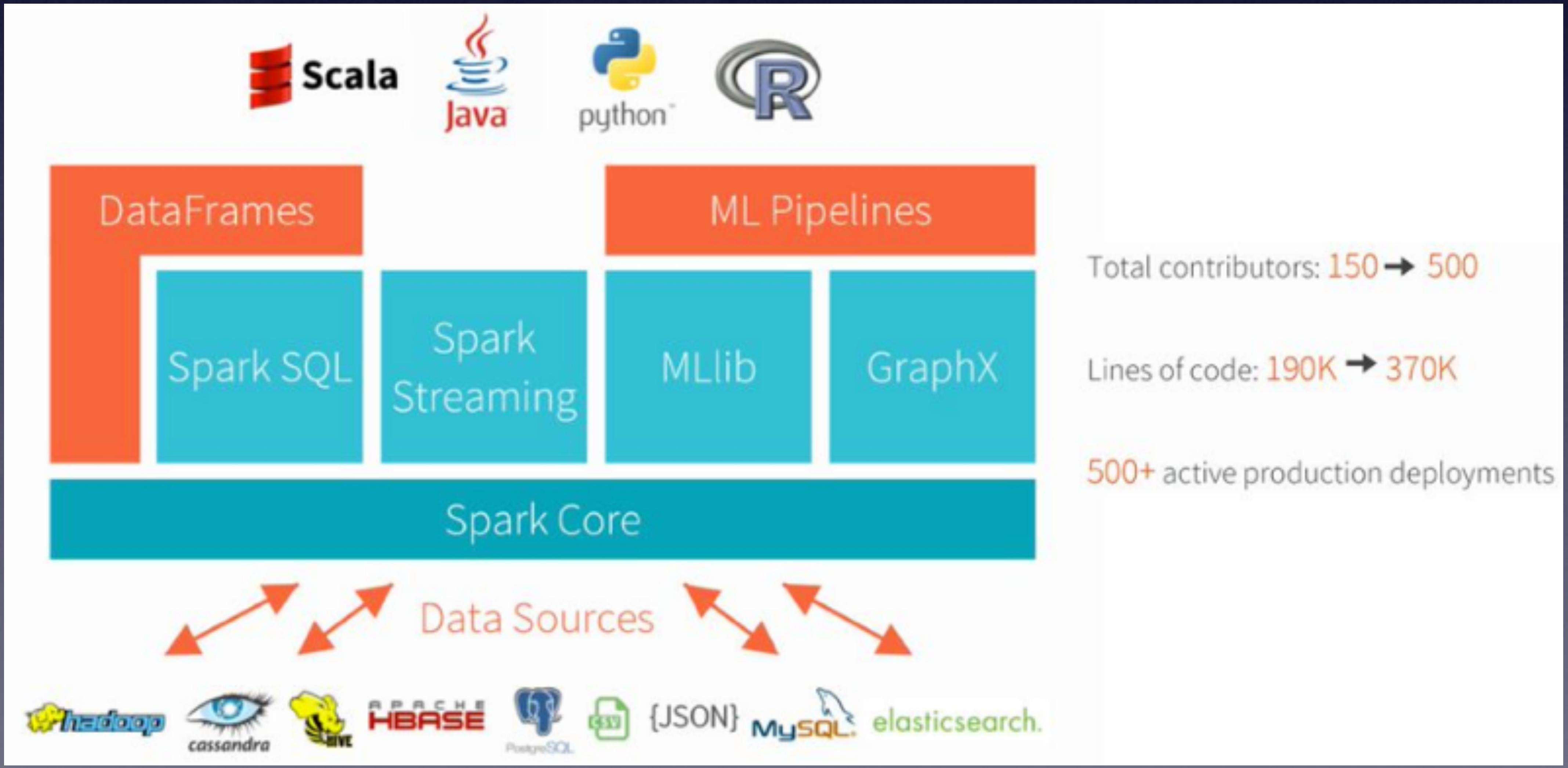
Maochen G.
mguan@us.ibm.com

2016.05

Spark overview

- General-purpose cluster computing system
- Written in Scala, also have high-level API's for Java, Python and R(pre-alpha)

- Environment Requirements:
- Java 7+, Python 2.6+, R 3.1+, Scala 2.10



MLLib in Spark

Maven dependencies

```
<dependency>
   <groupId>org.apache.spark</groupId>
   <artifactId>spark-mllib_2.11</artifactId>
   <version>1.6.1</version>
</dependency>
```

Two set of libraries:
1. org.apache.spark.ml
2. org.apache.spark.mllib

Use 2 only if the functionality doesn't exist in 1 !!!

ml

- Classification
  - Logistic regression
  - Decision tree classifier
  - Random forest classifier
  - Gradient-boosted tree classifier
  - Multilayer perceptron classifier
  - One-vs-Rest classifier (a.k.a. One-vs-All)
- Regression
  - Linear regression
  - Decision tree regression
  - Random forest regression
  - Gradient-boosted tree regression
  - Survival regression
- Decision trees
  - Inputs and Outputs
    - Input Columns
    - Output Columns
- Tree Ensembles
  - Random Forests
    - Inputs and Outputs
      - Input Columns
      - Output Columns (Predictions)
  - Gradient-Boosted Trees (GBTs)

Problem Type	Supported Methods
Binary Classification	linear SVMs, logistic regression, decision trees, random forests, gradient-boosted trees, naive Bayes
Multiclass Classification	logistic regression, decision trees, random forests, naive Bayes
Regression	linear least squares, Lasso, ridge regression, decision trees, random forests, gradient-boosted trees, isotonic regression

mllib packages

MLLib in Spark

Spark Concept Recall:

- SparkConf
- JavaSparkContext

Data Types:

- DataFrame
- JavaRDD<T> - Typical implementation for T is LabeledPoint or Vectors

SQLContext

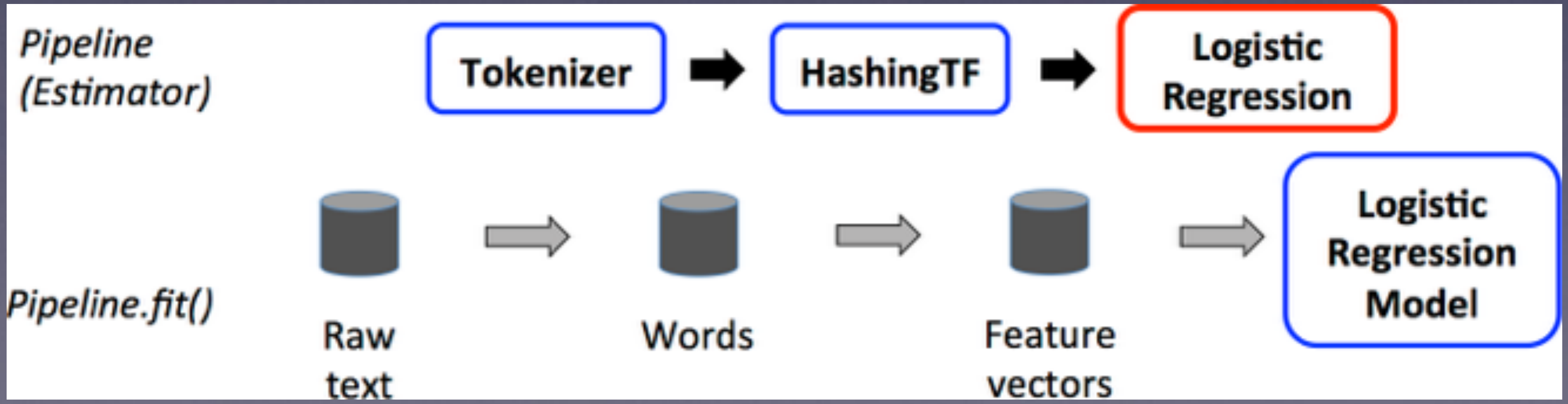
- Create DF.
- Execute SQL-format query over DF.

PipeLine

- Aggregation of stages, stage can be either learning algorithm or any annotation
- Pipeline pipeline = new Pipeline().setStages(new PipelineStage[]{tokenizer,hashingtf,lr});

Estimator

- Can be either a single specific learning alg. or Pipeline



MLLib in Spark

Pros:
1. Works well with large dataset.
2. Several good optimization libraries implemented.
3. Implemented full pipelines concept instead of discrete classifiers.
4. Have all training, prediction and cv pipelines.

Cons:
1. Pure ML library means you need to write adapter for application.
2. Only some of the core ML algorithms implemented currently.
3. Learning Curves for Developer.

Caveat:
Parallel data processing is ok.
Parallel core training process won't work for iterative ml algorithms

Problem Definition

Dataset: Student with 2 exam scores ranging from [0 - 100]
Predict: If grant admission for a potential student.

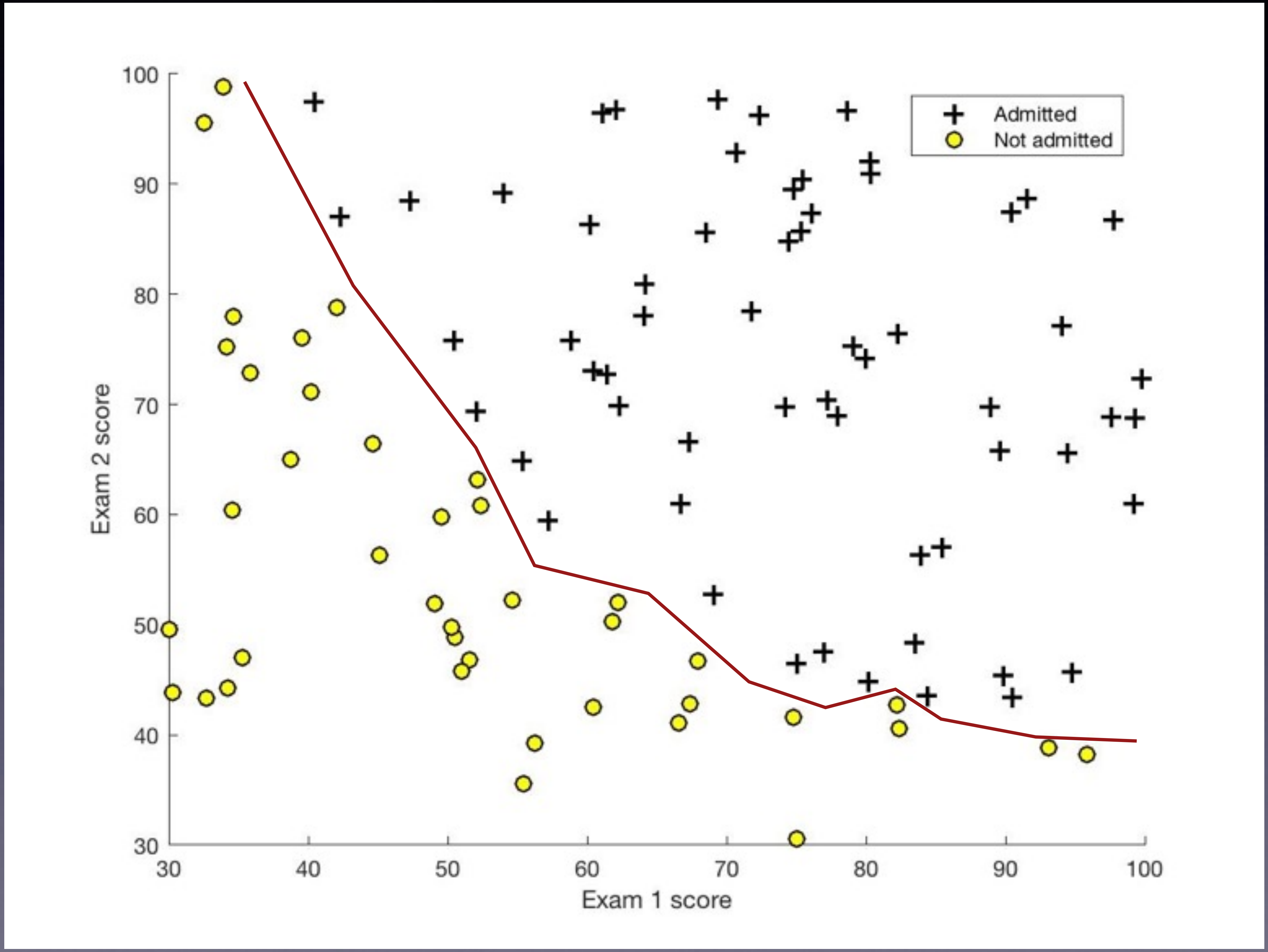
Dataset Size: 100
Binary Category: 0 - Decline, 1 - Admit

Examples:

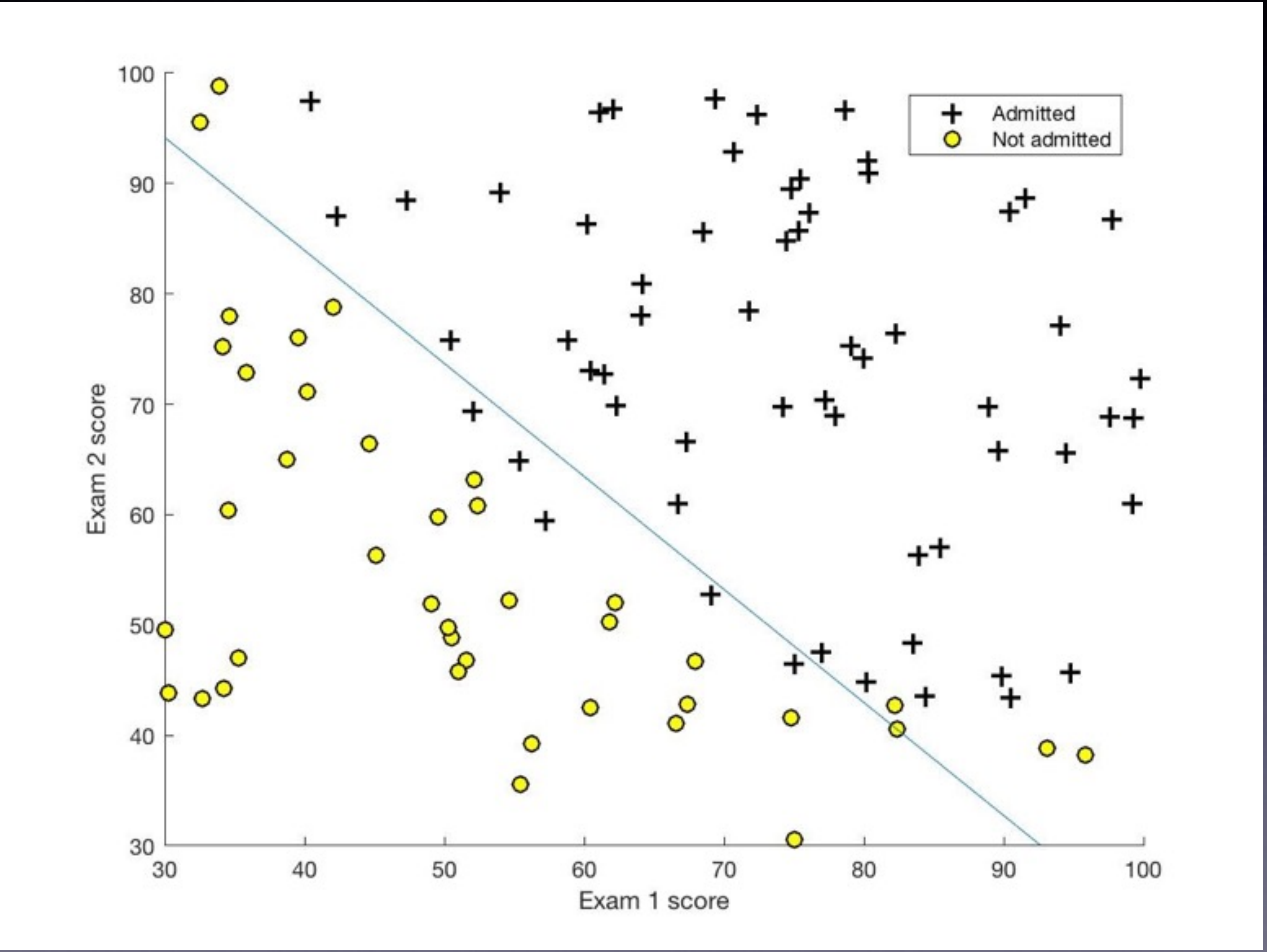
	Exam1,	Exam2,	Label
Student 1:	34.62365962451697,	78.0246928153624,	0
Student 2:	30.28671076822607,	43.89499752400101,	0
Student 3:	35.84740876993872,	72.90219802708364,	0

…

Visualize Dataset



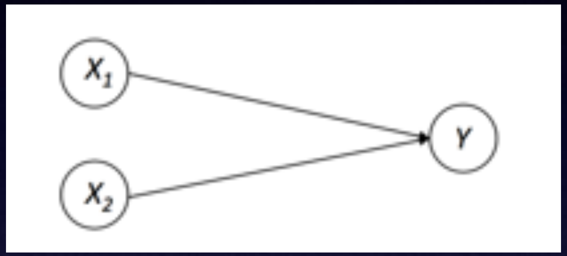
Visualize Dataset

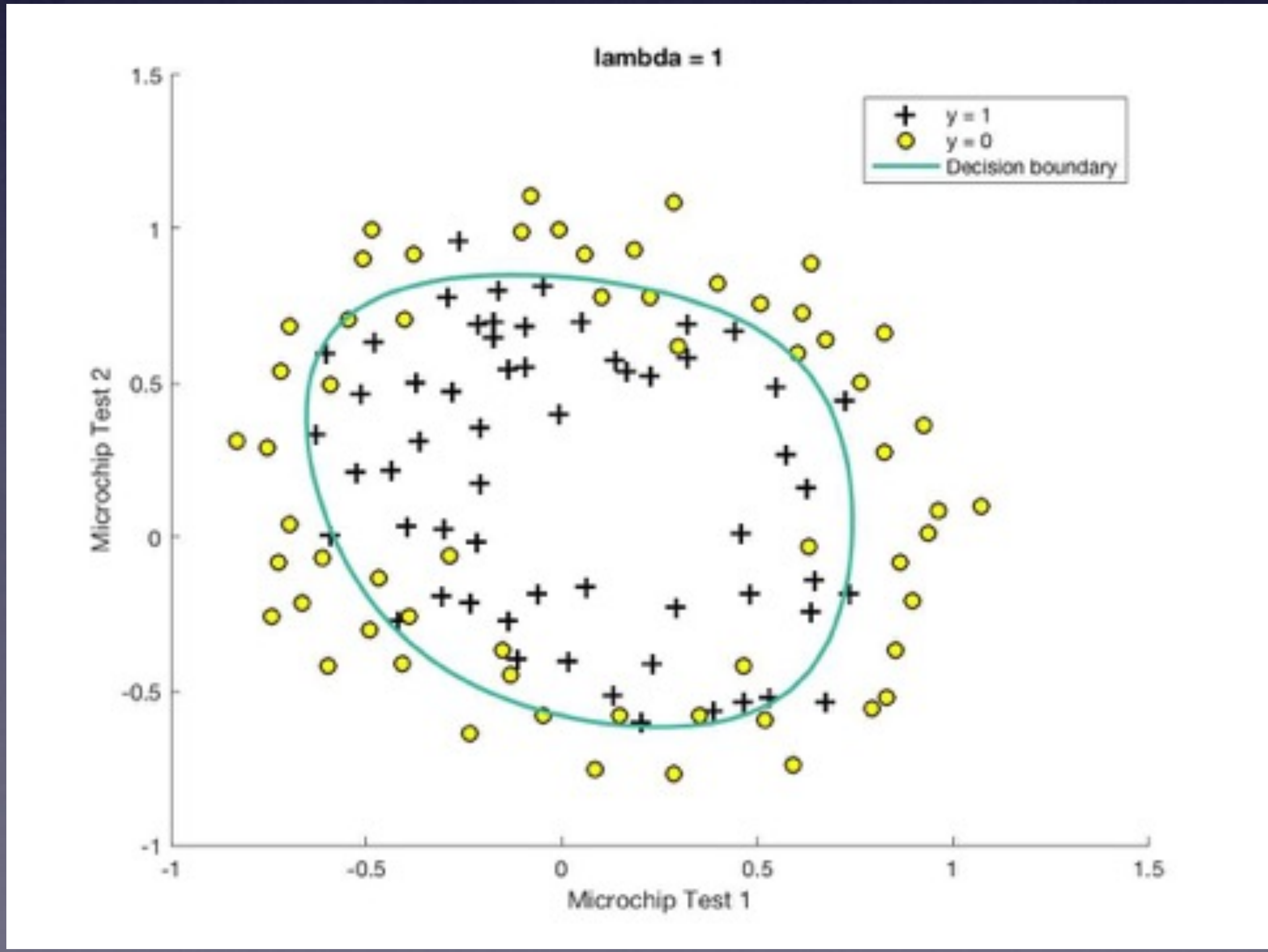


Logistic Regression (LR)

Log Linear model
This is NOT a regression

- Discriminative model P(y|x)
- LR is a special kind (binomial) of MaxEnt
- Features do not necessary to scale, but encouraged to do so.
- Not necessary for linear boundary.
- The plot uses polynomial feats, x^2, x1*x2, etc.



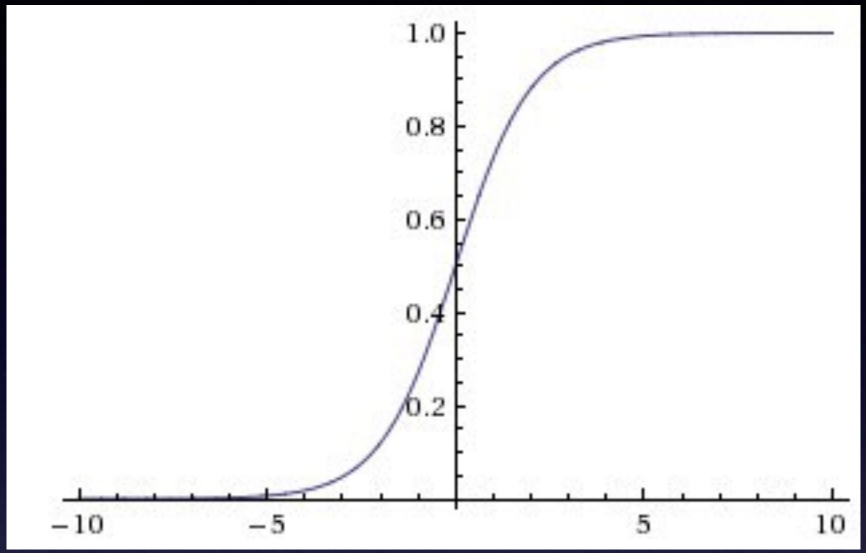


Non-linear decision boundary

Logistic Regression (LR)

Term Def:

1. Total Training Sample Size: m
2. Total features: n
3. i-th training sample: x_(i)
4. j-th dimension of i-th training sample: x_(i)_j
5. i-th training sample label: y_(i)
6. Weight vector θ (n dimensional)
7. h(θ) is the hypothesis function
8. sigmoid function == logistic function



Sigmoid Function

$$sigmoid(z) = \frac{1}{1 + e^{-z}} \qquad h(\theta) = sigmoid(\sum_{j=0}^{n} x_j^{(i)} \cdot \theta_j)$$

Training:

$$\begin{aligned} J(\theta) &= \frac{1}{m} \sum_{i=1}^{m} \mathrm{Cost}(h_\theta(x^{(i)}), y^{(i)}) \\ &= -\frac{1}{m}[\sum_{i=1}^{m} y^{(i)} \log h_\theta(x^{(i)}) + (1 - y^{(i)}) \log (1 - h_\theta(x^{(i)}))] \end{aligned}$$

Goal: Optimize θ vector to minimize J(θ)

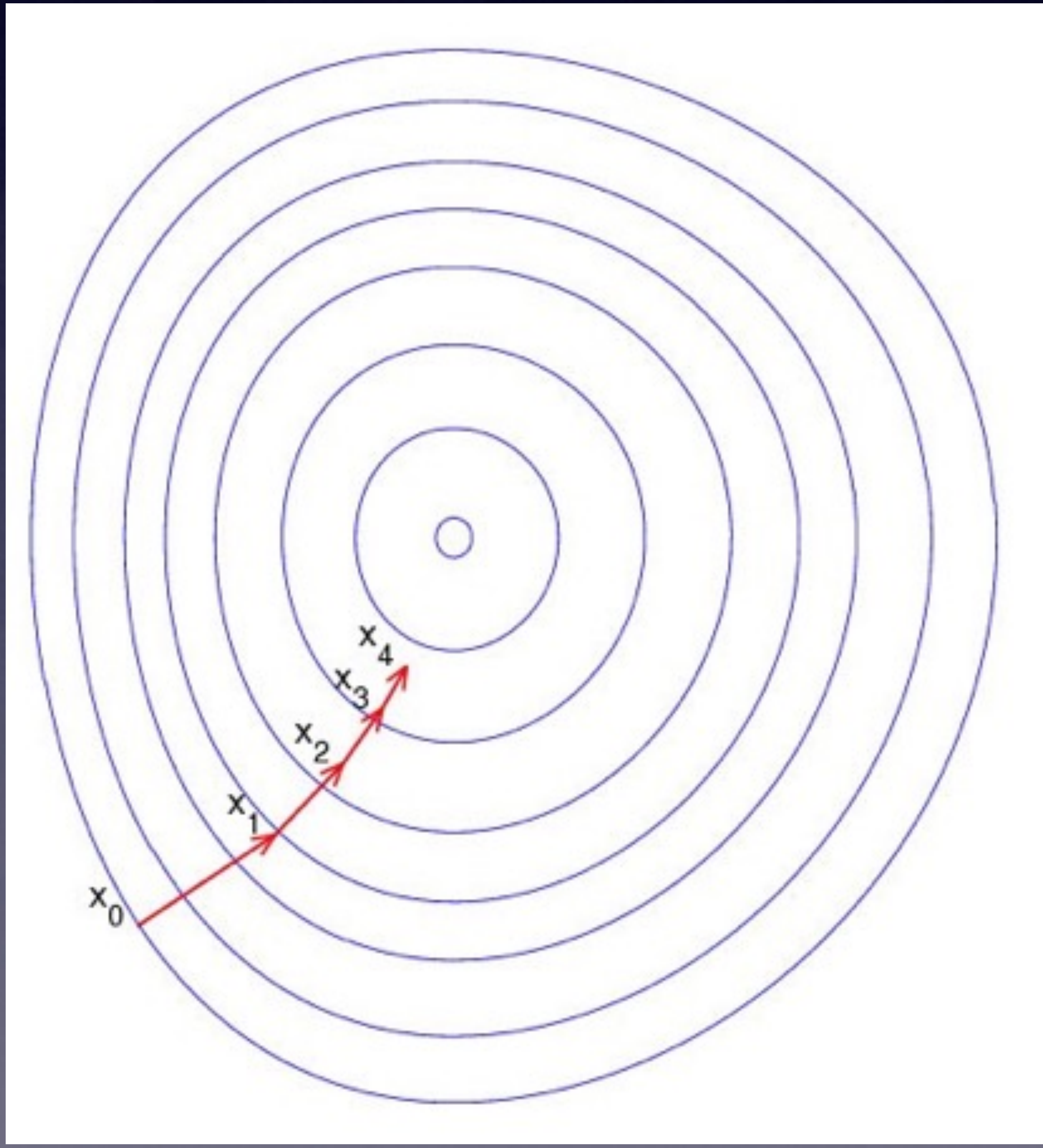
Optimizer: Gradient Descent/SGD/LBFGS

Predict:

$$y = \begin{cases} 0 & h(\theta) < 0.5 \\ 1 & otherwise \end{cases}$$

Gradient Descent

$$J(\theta) = \frac{1}{m}\sum_{i=1}^{m}\mathrm{Cost}(h_\theta(x^{(i)}), y^{(i)})$$
$$= -\frac{1}{m}[\sum_{i=1}^{m} y^{(i)}\log h_\theta(x^{(i)}) + (1-y^{(i)})\log(1-h_\theta(x^{(i)}))]$$



Coding Time

Weights learned with LR+GD in Matlab by fminunc:

-24.932775, 0.204406, 0.199616 (First is intercept)

Code snippet also available at
http://www.maochen.org/playground/playground.html