EE 542

Lecture 18: Spark on Cloud

Internet and Cloud Computing

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Slides from UC Berkeley AMP Lab

MapReduce

- Programming model for data-intensive computing on commodity clusters
- Pioneered by Google
  - Processes 20 PB of data per day
- Popularized by Apache Hadoop project
  - Used by Yahoo!, Facebook, Amazon, …
- Industry Trending Toward Spark
  - Quickly Being Adopted by Big Data Industry

Limitations of MapReduce

- MapReduce is great at one-pass computation, but inefficient for *multi-pass* algorithms
- No efficient primitives for data sharing
  - State between steps goes to distributed file system
  - Slow due to replication & disk storage
  - No control of data partitioning across steps

Spark Programming Model

- Extends MapReduce with primitives for efficient data sharing
  - "Resilient distributed datasets"
- Open source in Apache Incubator
  - Growing community with 100+ contributors
- APIs in Java, Scala & Python

Resilient Distributed Datasets (RDDs)

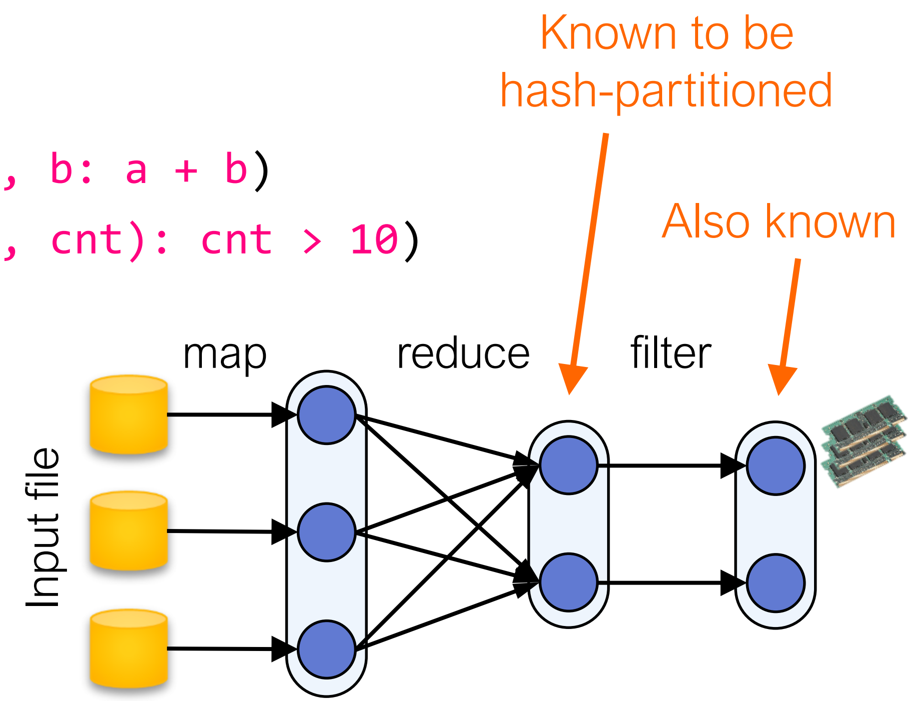
- Collections of objects stored across a cluster
- User-controlled partitioning & storage (RAM, disk, …)
- Automatically rebuilt on failure

```
urls = spark.textFile("hdfs://...")
records = urls.map(lambda s: (s, 1))
counts = records.reduceByKey(lambda a, b: a + b)
bigCounts = counts.filter(lambda (url, cnt): cnt > 10)


bigCounts.cache()

bigCounts.filter(
  lambda (k,v): "news" in k).count()

bigCounts.join(otherPartitionedRDD)
```



Spark

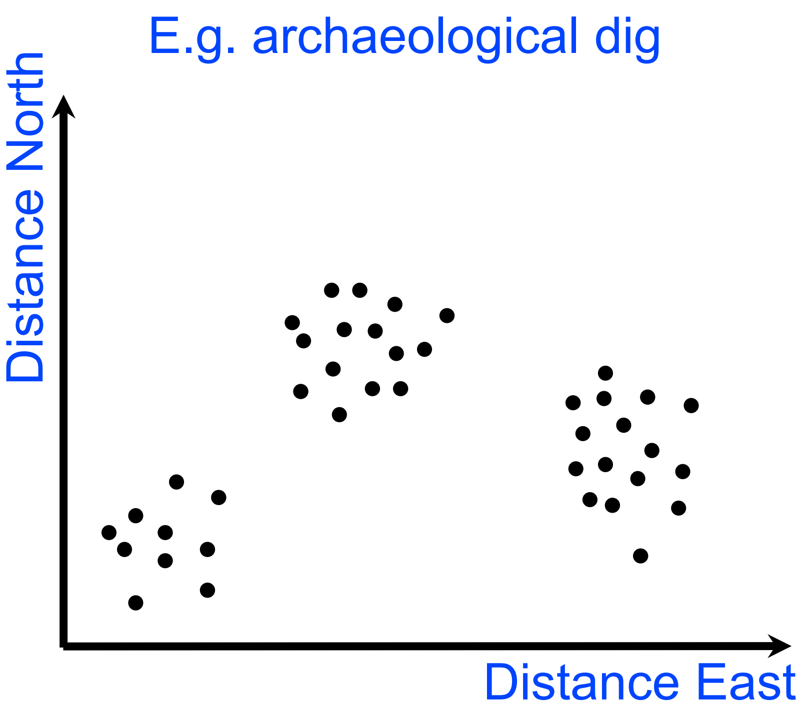
- In-Memory Computation
  - For 64-bit computers TB of data in RAM
  - Designed to transform data in-mem and not in disk
  - Supports parallel distributed processing of data
  - 100x in memory and 10x on disk then Hadoop
- General programming model
  - Use normal sequential programming
  - No need for maps and reduce operations

Spark: Key Advantages

- Ability for On-disk Data Sorting
  - Tuned for large scale of data sorting on disk
  - The world record of on-disk large scale data sorting
- Efficient Use of Cache
  - Mesos which is a distributed system kernel for caching the intermediate dataset
  - Multiple iterations on the cached dataset
- In-memory Tuned Library
  - MLlib library for in-memory tuned operations
- Faster Launch with Virtual Machine

Clustering

Grouping data according to similarity



Clustering

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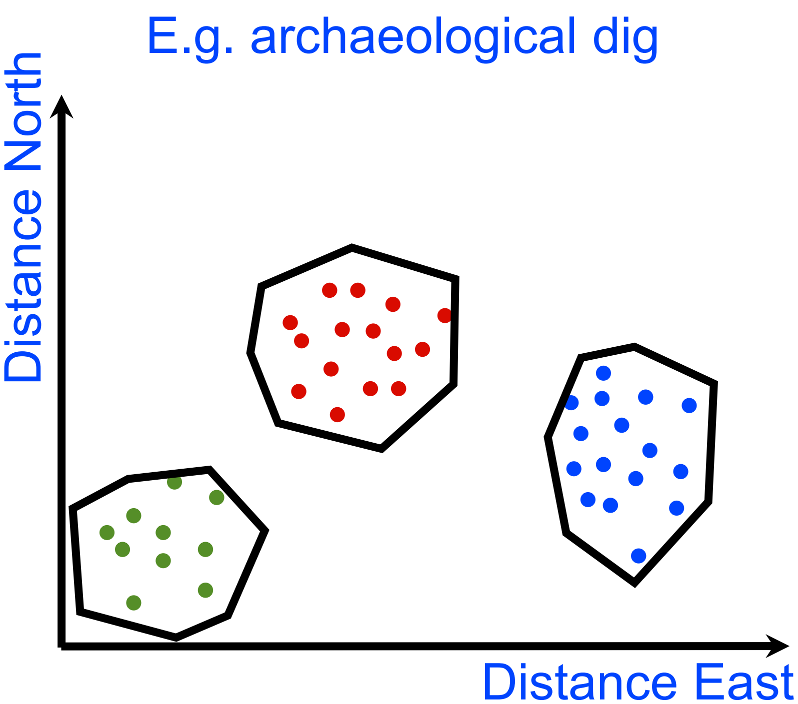
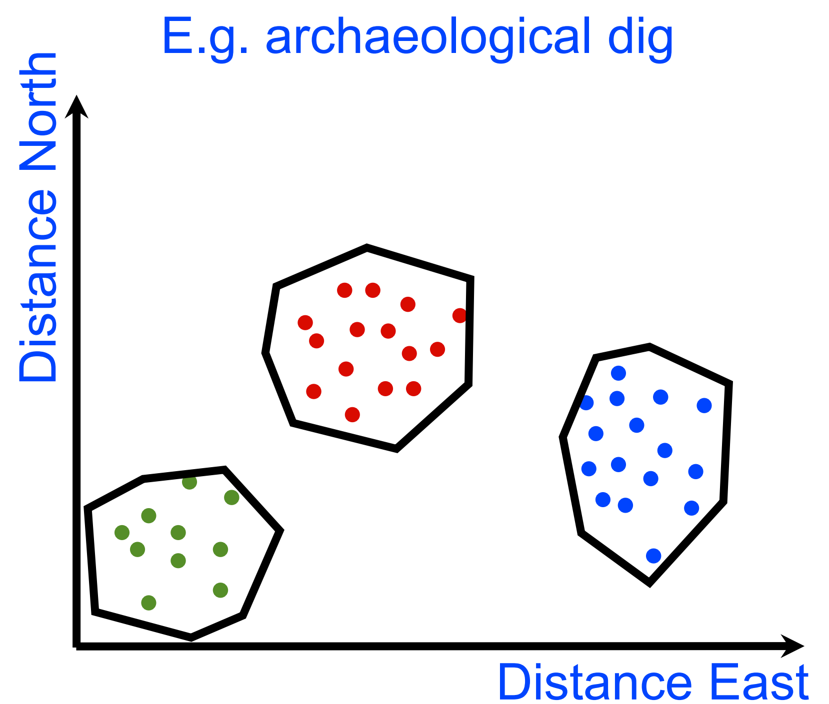


Clustering with Spark

K-Means: preliminaries

Benefits

- Popular
- Fast
- Conceptually straightforward

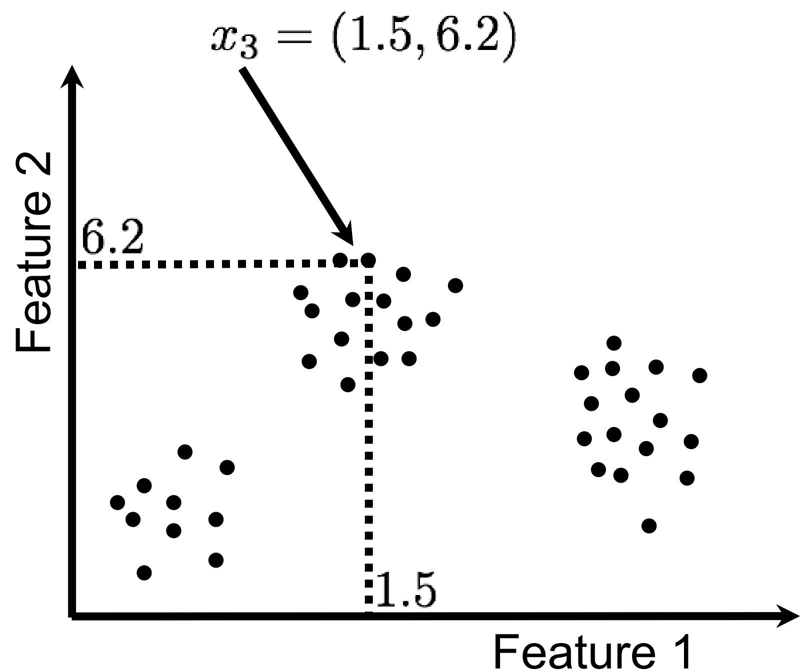


Clustering with Spark

K-Means: preliminaries

Data: Collection of values

```
data = lines.map(line=>
    parseVector(line))
```

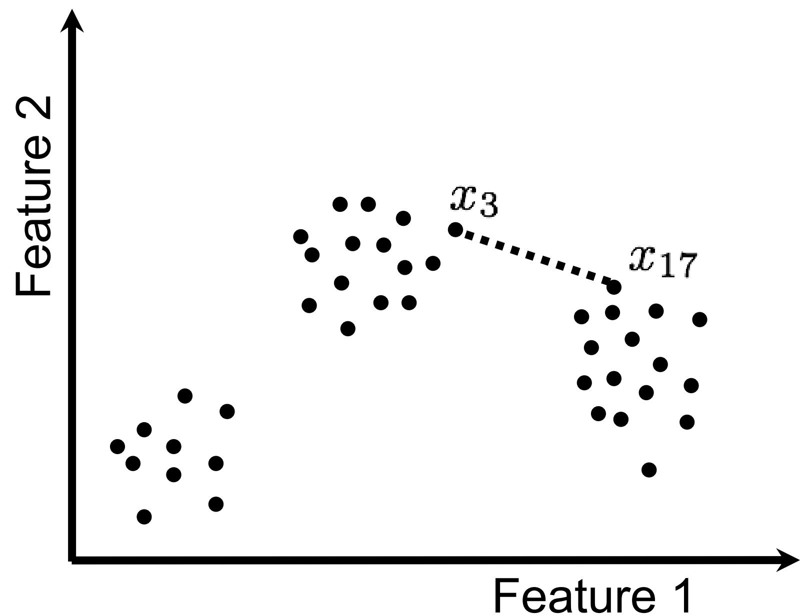


Clustering with Spark

K-Means: preliminaries

Dissimilarity:
Squared Euclidean distance

```
dist = p.squaredDist(q)
```



Clustering with Spark

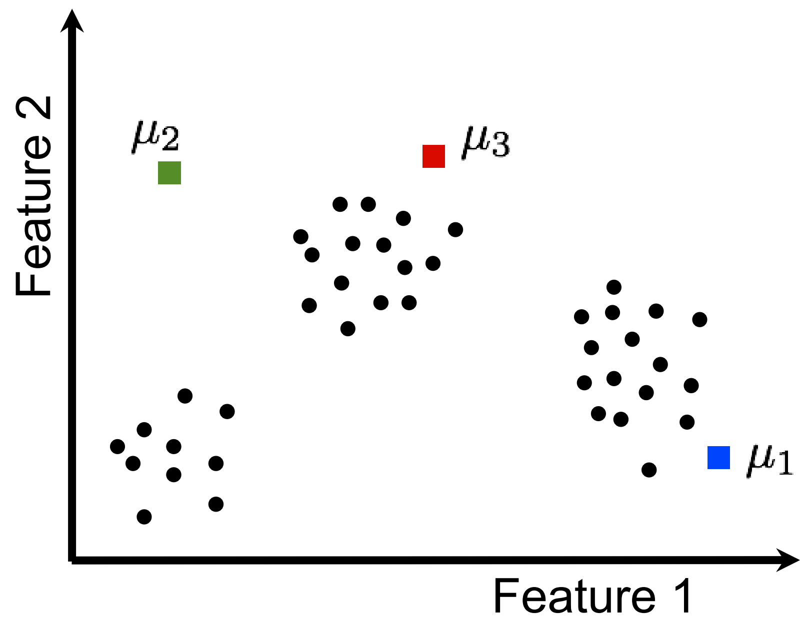
K-Means: preliminaries

K = Number of clusters

$\mu_1, \mu_2, \ldots, \mu_K$

Data assignments to clusters

$S_1, S_2, \ldots, S_K$



Clustering with Spark

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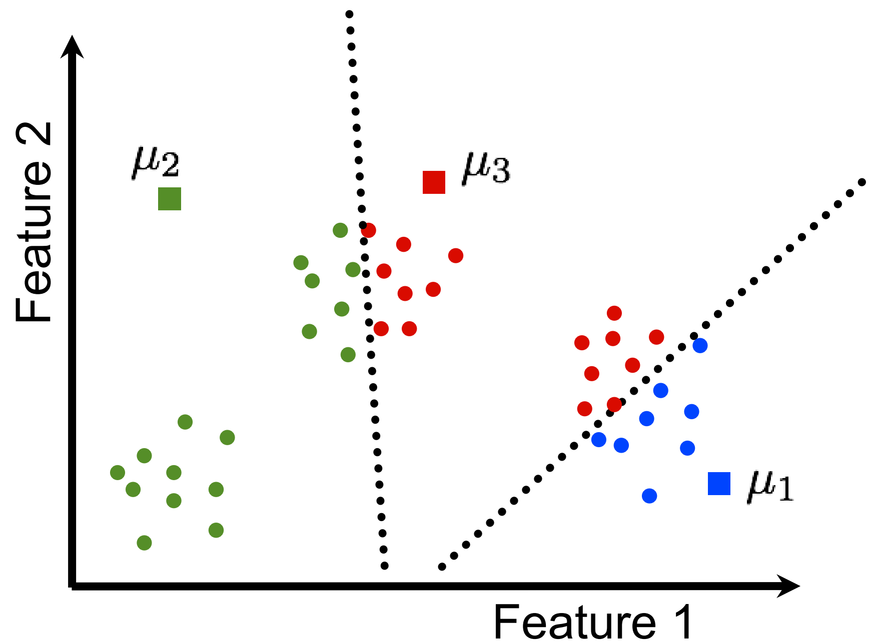
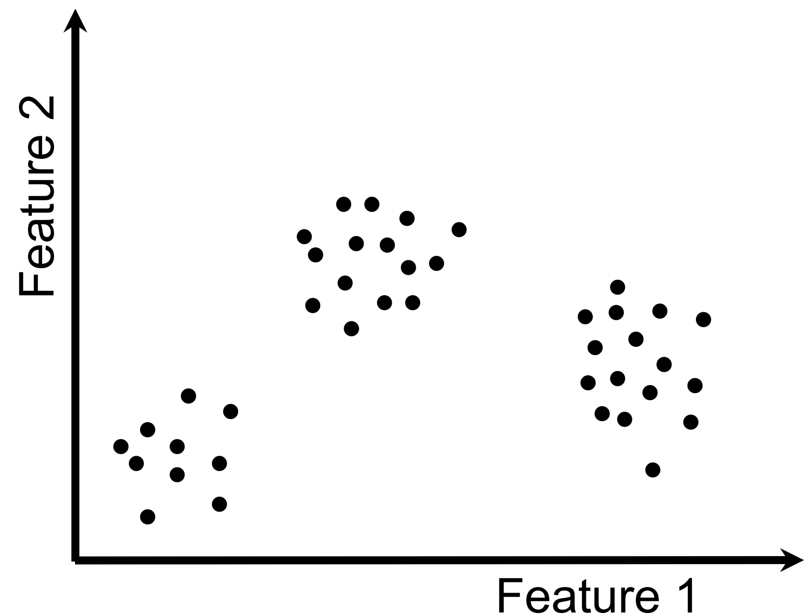


Clustering with Spark

K-Means Algorithm

- Initialize K cluster centers
- Repeat until convergence:
  - Assign each data point to the cluster with the closest center.
  - Assign each cluster center to be the mean of its cluster’s data points.



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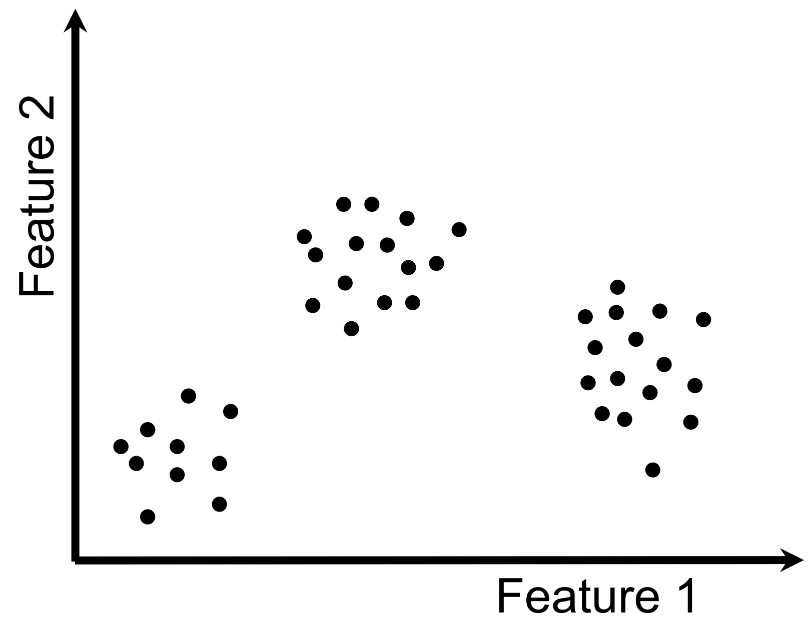

Clustering with Spark

K-Means Algorithm

- Initialize K cluster centers

```
centers = data.takeSample(
    false, K, seed)
```

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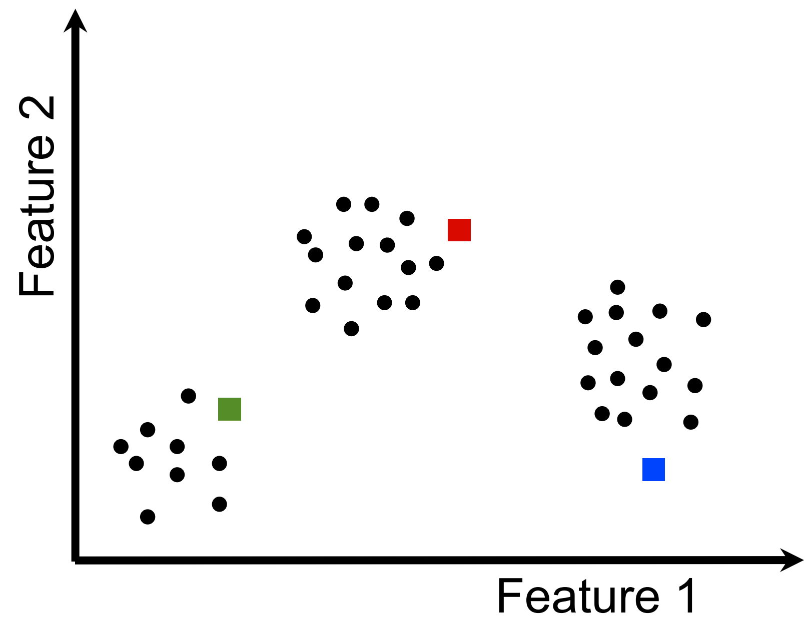

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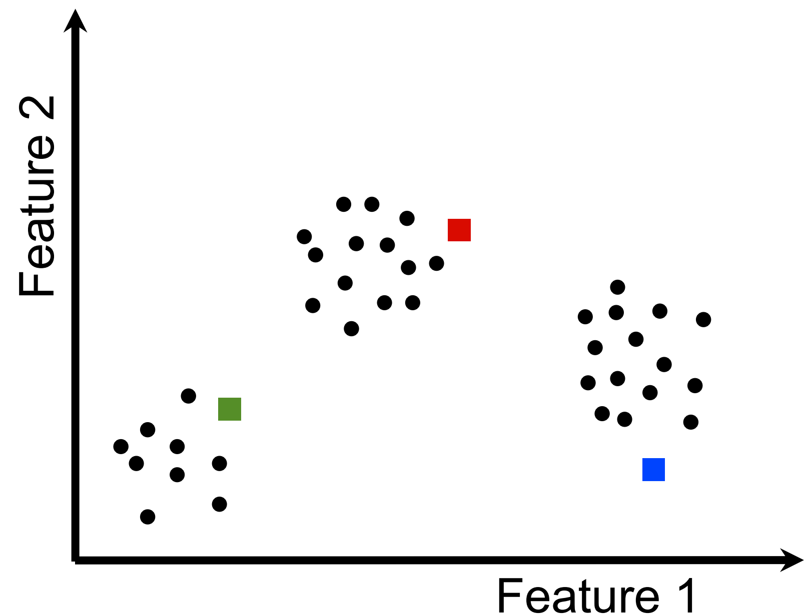

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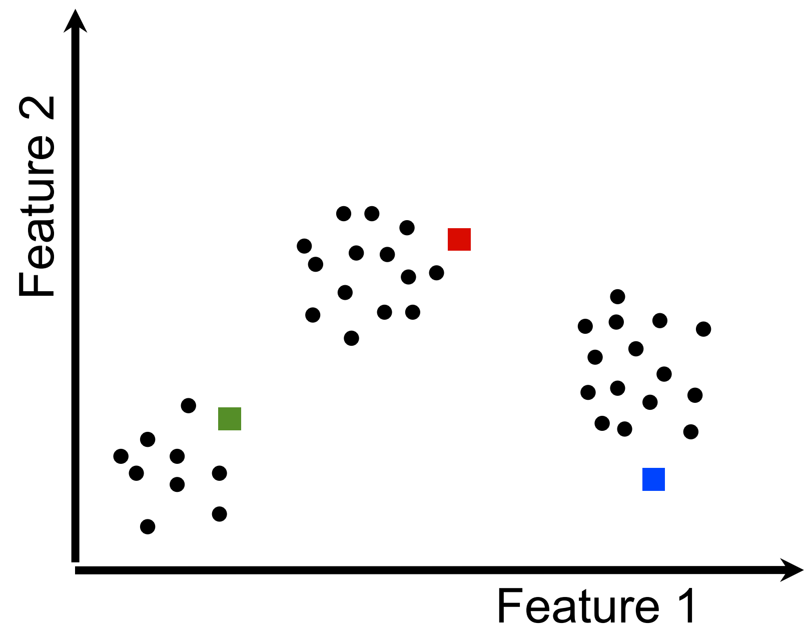

Clustering with Spark

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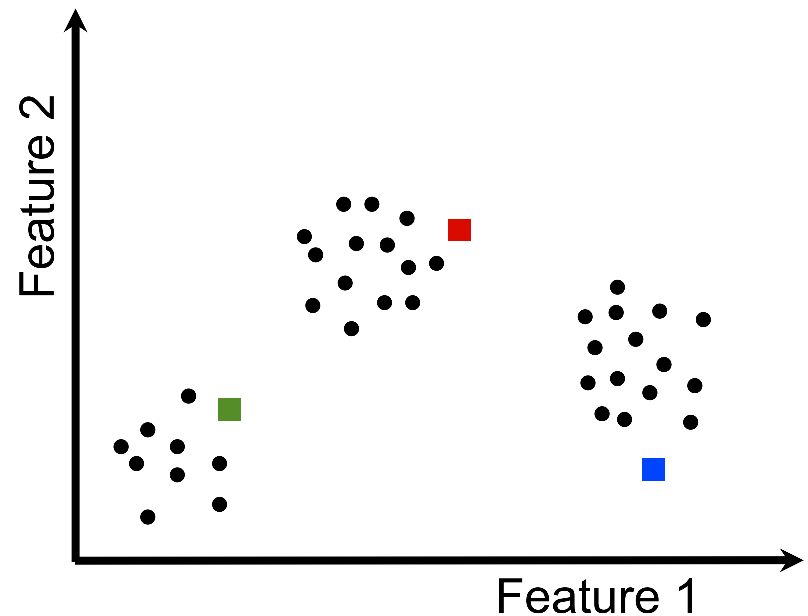
Assign each cluster center to be the mean of its cluster's data points.



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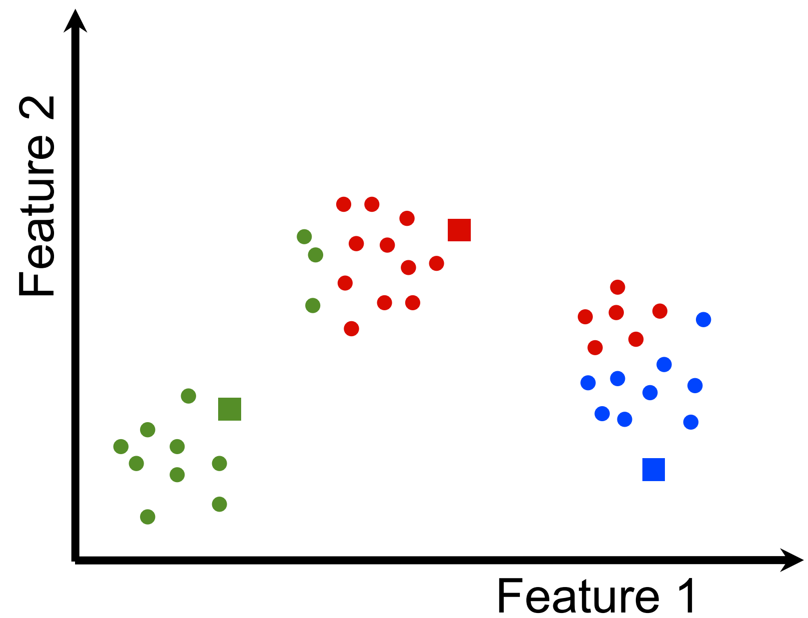

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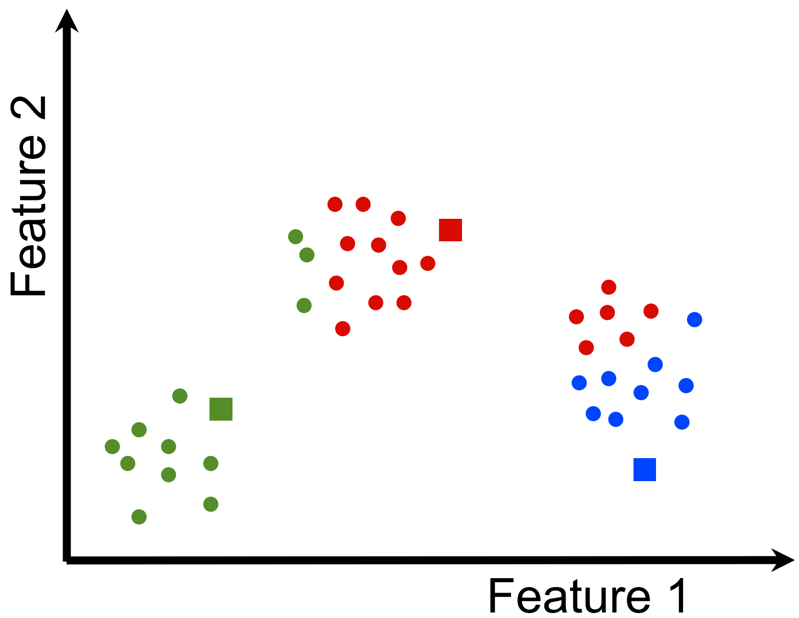

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pointsGroup =
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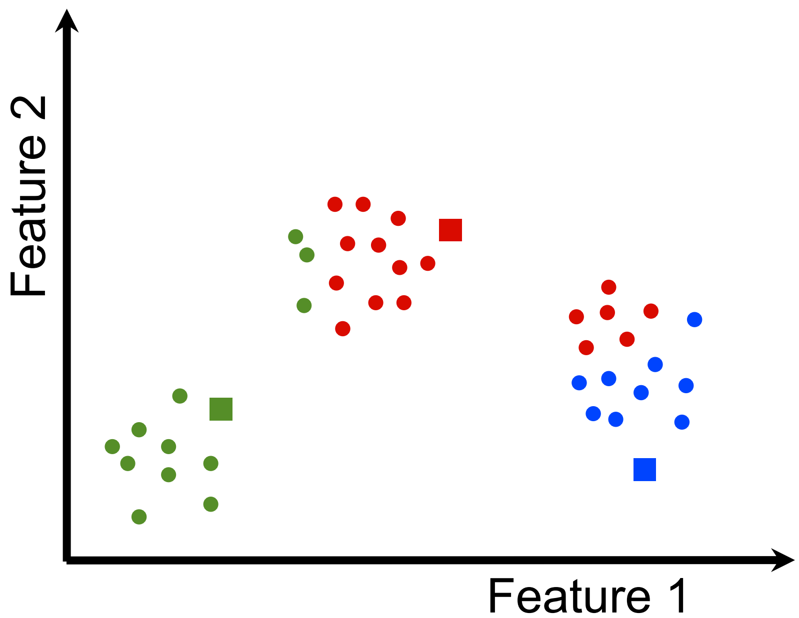

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- Repeat until convergence:

```
closest = data.map(p =>

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pointsGroup =
    closest.groupByKey()

newCenters = pointsGroup.mapValues(
    ps => average(ps))
```

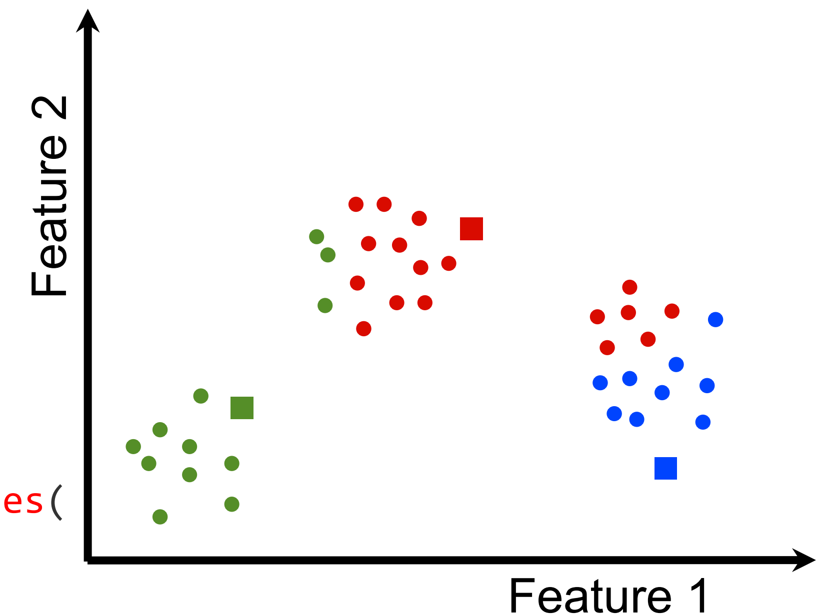

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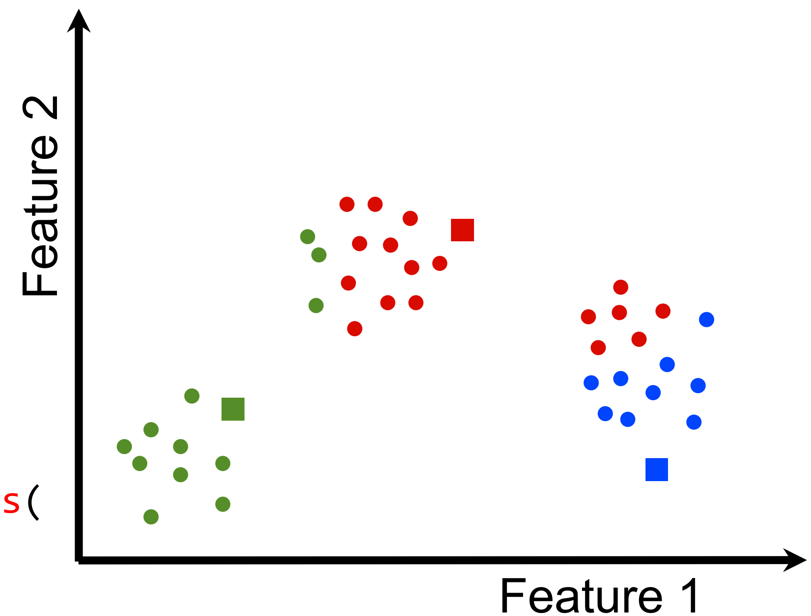

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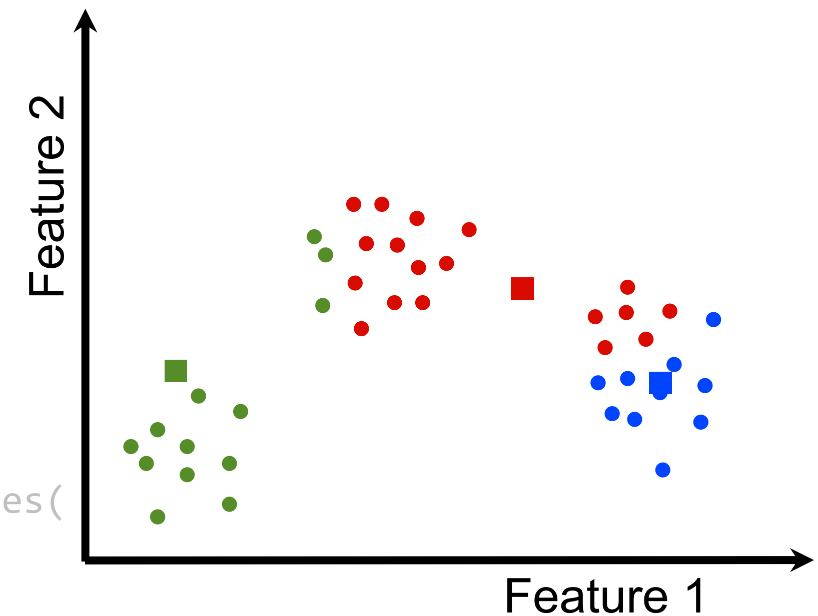

Clustering with Spark

K-Means Algorithm

- Initialize K cluster centers

```
centers = data.takeSample(
    false, K, seed)
```

- Repeat until convergence:

```
while (dist(centers,
            newCenters) > ε)
closest = data.map(p =>
   (closestPoint(p,centers),p))
pointsGroup =
    closest.groupByKey()
newCenters =pointsGroup.mapValues(
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```

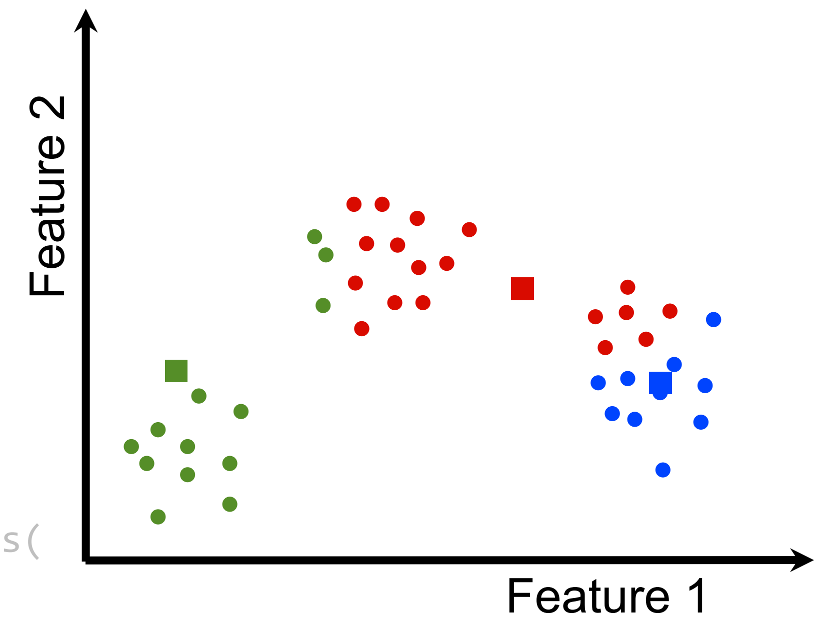

Clustering with Spark

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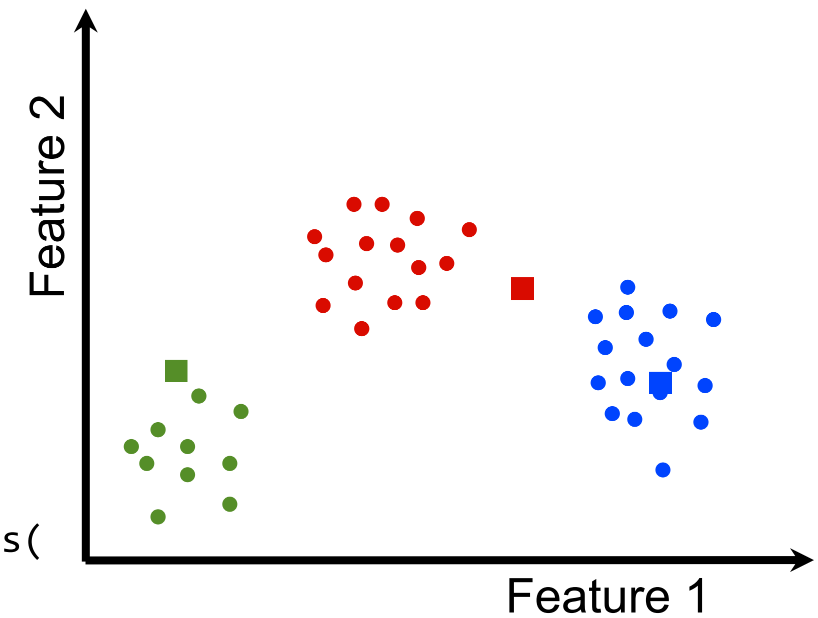
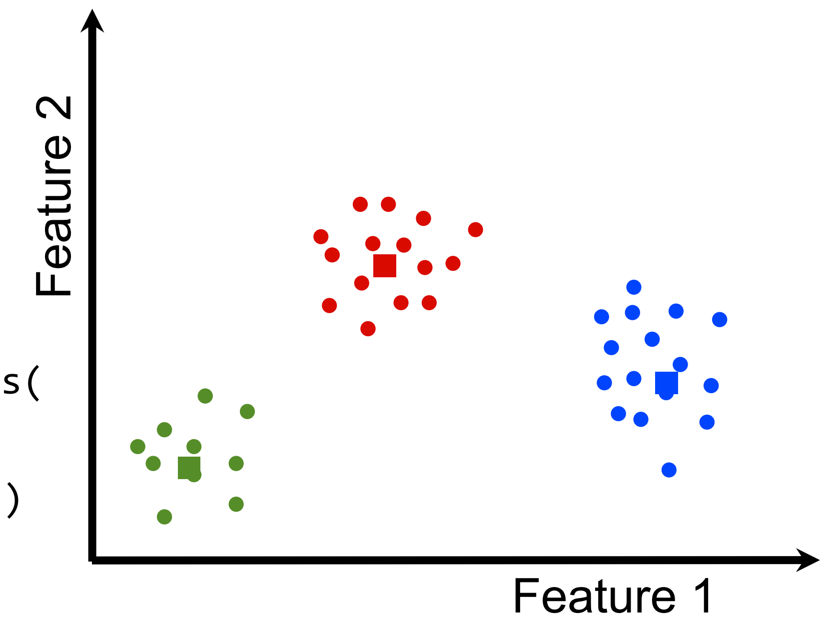


Clustering with Spark

K-Means Source

```
centers = data.takeSample(
    false, K, seed)
while (d > ε)
{
  closest = data.map(p =>
     (closestPoint(p,centers),p))
  pointsGroup =
      closest.groupByKey()
  newCenters =pointsGroup.mapValues(
      ps => average(ps))
  d = distance(centers, newCenters)
  centers = newCenters.map(_)
}
```

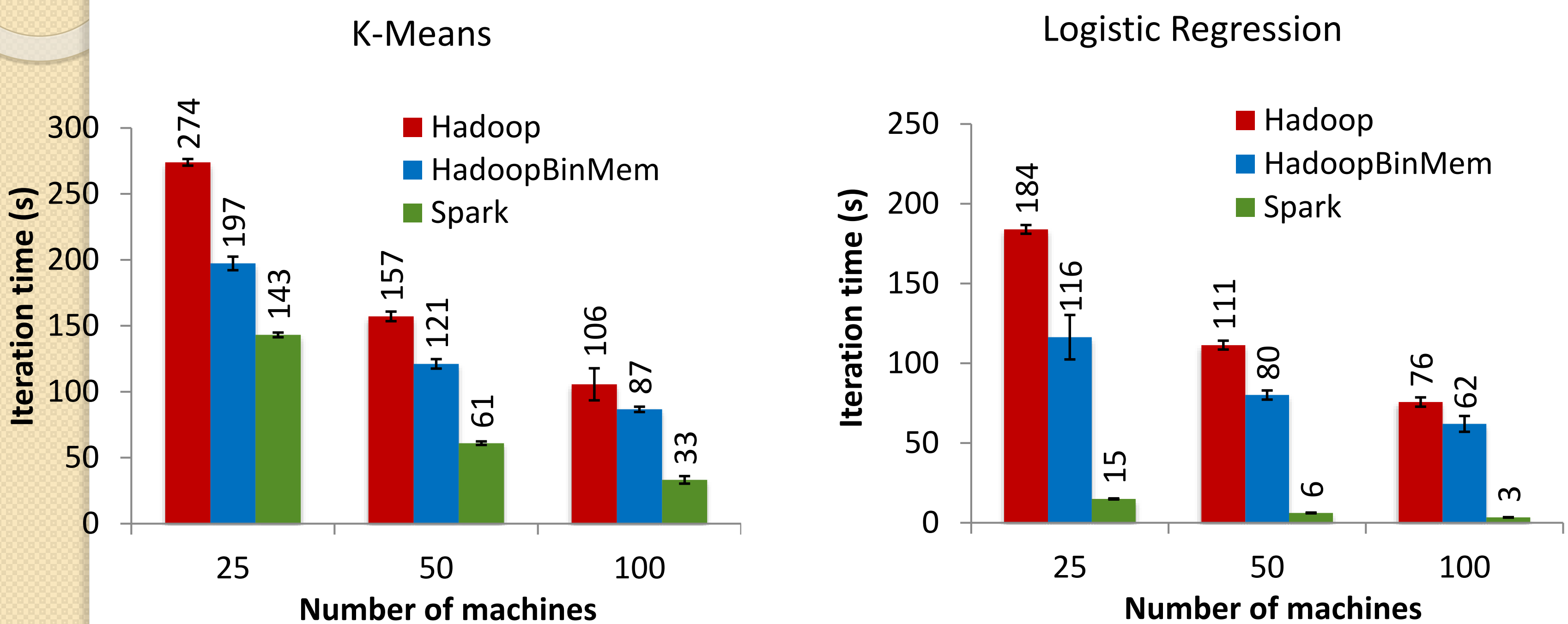


Clustering with Spark

Ease of use

- Interactive shell:
  - Useful for featurization, pre-processing data
- Lines of code for K-Means
  - Spark ~ 90 lines
  - Hadoop/Mahout ~ 4 files, > 300 lines

Performance



[Zaharia et. al, NSDI'12]

K-Means in MLlib

- http://spark.apache.org/docs/latest/mllib-clustering.html#k-means
- Available for Multiple Languages
  - Scala
  - Java
  - Python