

Técnica Map-Reduce

Agradecimientos

- ▶ Este curso es una versión libre del curso on-line Introducción a la Ciencia de Datos (Bill Howe, Univ. de Washington) <https://www.coursera.org/course/datasci>

Escalabilidad de Datos

Operar con un volumen arbitrariamente grande de datos.

- ▶ En el pasado esta noción se restringía a operar con un volumen que superara el tamaño de la memoria (RAM)
 - ▶ La información se trae de disco y se procesa en porciones de tamaño más reducido
 - ▶ Las bases de datos convencionales resuelven este problema
- ▶ A partir del 2000 la alta disponibilidad de los servicios en Internet requiere otra solución
 - ▶ La latencia de los discos tiene tiempos de respuesta inaceptables
 - ▶ La información tiene que estar disponible en la memoria principal
 - ▶ Solución: clusters de muchas máquinas baratas trabajando cooperativamente en un mismo problema

Escalabilidad del Procesamiento de Datos

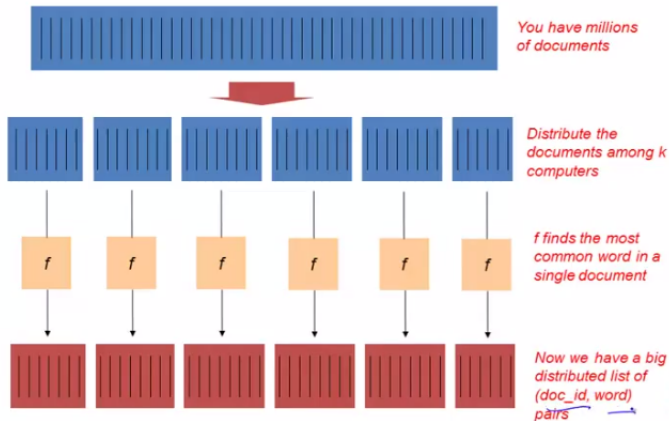
Otro aspecto importante es la complejidad de los algoritmos que procesan los datos

- ▶ En el pasado los algoritmos de complejidad polinomial N^m eran considerados aceptables
 - ▶ A medida que m crece, el impacto en un gran volumen de datos convierte al algoritmo en inaceptable
- ▶ En un cluster de k máquinas, la complejidad decrece N^m/k , esta solución es aceptable
- ▶ En la actualidad algunas aplicaciones requieren que su complejidad sea $N * \log(N)$
 - ▶ Aplicaciones de procesamiento de streaming de datos
 - ▶ Es el tiempo mínimo para hacer una sólo pasada y guardar cada dato en un árbol

Procesamiento Distribuido en un Cluster

W

Find the most common word in each document



Histograma de Palabras

W

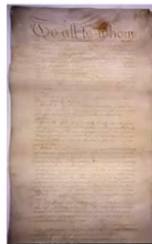
What if we want to compute the word frequency across *all* documents?



US Constitution



Declaration of Independence

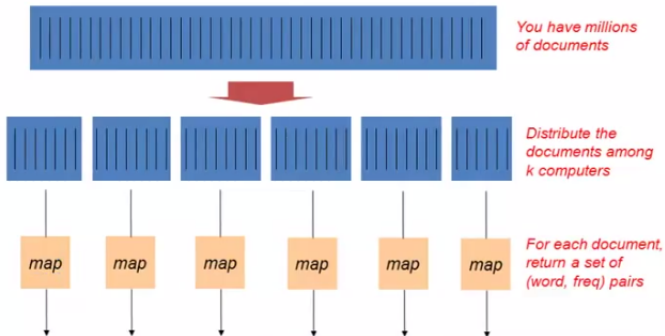


Articles of Confederation

(people, 78)
(government, 123)
(assume, 23)
(history, 38)
...

Fase de Map

V Compute the word frequency **across** 5M documents

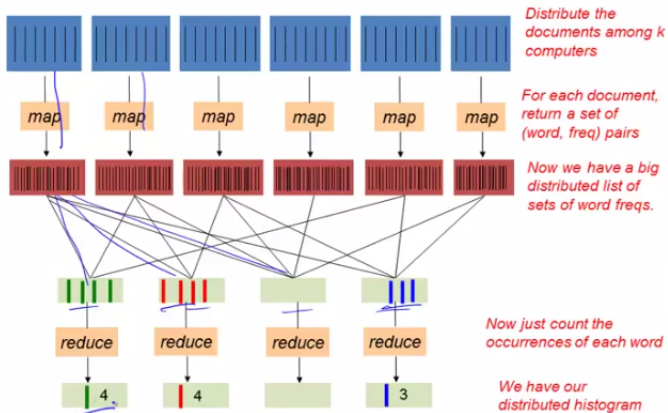


Now what?

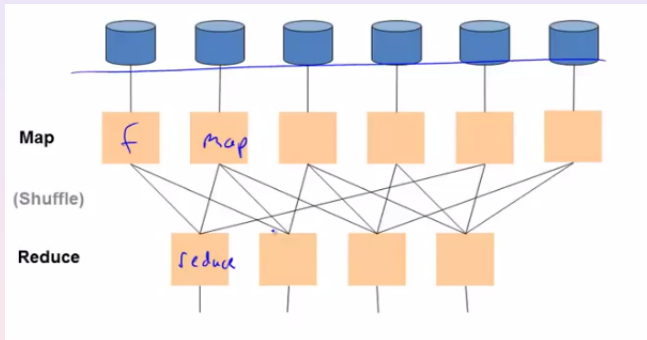
- But we don't want a bunch of little histograms – we want one big histogram.
- How can we make sure that a single computer has access to every occurrence of a given word regardless of which document it appeared in?

Fase de Reduce

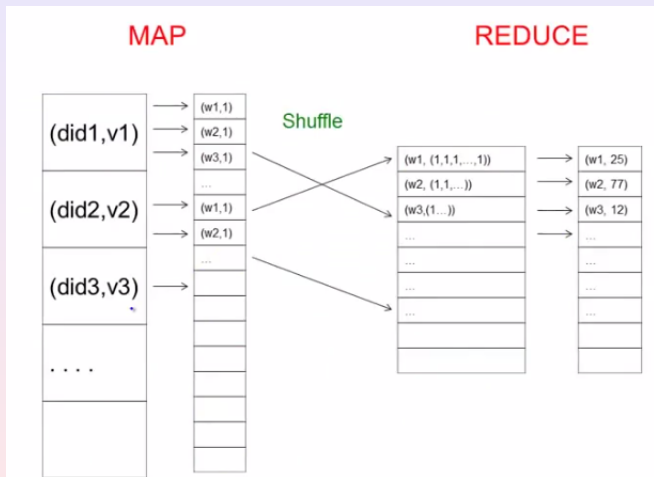
W Compute the word frequency **across** 5M documents



Map-Reduce



Map-Reduce



Map-Reduce

- ▶ Map-Reduce es un modelo de programación de alto nivel para procesamiento paralelo de grandes volúmenes de datos
- ▶ Hay que programar exclusivamente las fases de `map()` y de `reduce()`
- ▶ El modelo se ocupa de la distribución, la tolerancia a fallos, etc.
- ▶ Artículo de Google de 2004
- ▶ Implementación más popular es Hadoop (Apache)

Map-Reduce

Map-Reduce está compuesto por estas fases:

1. En cada nodo la función *mapper* se encarga de transformar los items en un conjunto de pares clave-valor
2. Se agrupan los pares clave-valor que tienen la misma clave
3. La función *reducer* procesa los valores asociados a cada clave y genera un output

Map-Reduce

```
map(String input_key, String input_value):
```

```
// input_key: document name
```

```
// input_value: document contents
```

```
for each word w in input_value:
```

```
    EmitIntermediate(w, 1);
```

("history", 1)

```
reduce(String intermediate_key, Iterator intermediate_values):
```

```
// intermediate_key: word
```

```
// intermediate_values: ????
```

```
int result = 0;
```

```
for each v in intermediate_values:
```

```
    result += v;
```

```
EmitFinal(intermediate_key, result);
```

(history, 25)

slide source: Google, Inc.

Documentos Grandes

Si eventualmente un documento fuese lo suficientemente grande como para no poder ser procesado por una sola computadora en el cluster, el filesystem subyacente lo parte para que sea procesado por varias computadoras.

Split the document into chunks and process each chunk on a different computer

Chunk 1

Chunk 2

Abridged Declaration of Independence

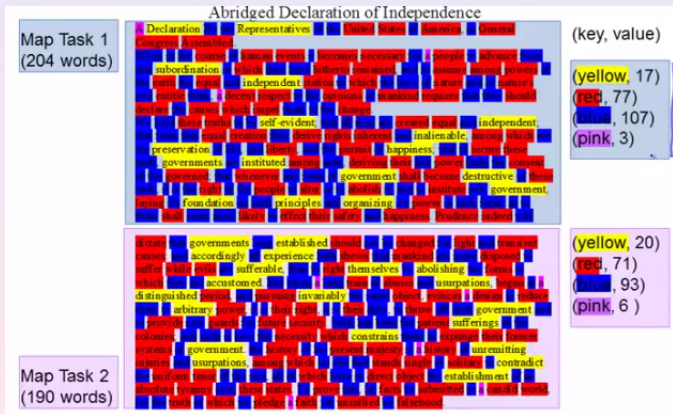
A Declaration By the Representatives of the United States of America, in General Congress Assembled.

When in the course of human events it becomes necessary for a people to advance from that subordination in which they have hitherto remained, and to assume among powers of the earth the equal and independent station to which the laws of nature and of nature's god entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the change.

We hold these truths to be self-evident, that all men are created equal and independent; that from that equal creation they derive rights inherent and inalienable, among which are the preservation of life, and liberty, and the pursuit of happiness; that to secure these ends, governments are instituted among men, deriving their just power from the consent of the governed; that whenever any form of government shall become destructive of these ends, it is the right of the people to alter or to abolish it, and to institute new government, laying its foundation on such principles and organizing its power in such form, as to them shall seem most likely to effect their safety and happiness. Prudence indeed will dictate that governments long established should not be changed for light and transient causes: and accordingly all experience hath shewn that mankind are more disposed to suffer while evils are sufferable, than to right themselves by abolishing the forms to which they are accustomed. But when a long train of abuses and usurpations, begun at a distinguished period, and pursuing invariably the same object, evinces a design to reduce them to arbitrary power, it is their right, it is their duty, to throw off such government and to provide new guards for future security. Such has been the patient sufferings of the colonies; and such is now the necessity which constrains them to expunge their former systems of government. the history of his present majesty is a history of unremitting injuries and usurpations, among which no one fact stands single or solitary to contradict the uniform tenor of the rest, all of which have in direct object the establishment of an absolute tyranny over these states. To prove this, let facts be submitted to a candid world, for the truth of which we pledge a faith yet unswerving by falsehood.

Ejemplo Palabras por Tamaño (Map)

En este ejemplo el objetivo es contar la cantidad de palabras cuya longitud es chica, mediana o grande.



Ejemplo Palabras por Tamaño (Reduce)

Map task 1

A Declaration by the Representatives of the United States of America, in General Congress Assembled.

When in the course of human events it becomes necessary for a people to advance from the subordination in which they have hitherto remained, and to assume among powers of the earth the equal and independent station to which the laws of nature and of nature's god entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the change.

We hold these truths to be self-evident, that all men are created equal, and independent; that from that equal condition they derive rights inherent and inalienable, among which are the preservation of life, and liberty; and the pursuit of happiness. That to secure these ends, governments are instituted among men, deriving their just powers from the consent of the governed, that whenever any form of government shall become destructive of these ends, it is the right of the people to alter or to abolish it, and to institute new government, laying its foundation on such principles, and organizing it in such form, as to them shall seem most likely to effect their safety and happiness. Prudence would not

(yellow, 17)

(red, 77)

(blue, 107)

(pink, 3)

Map task 2

discern that governments long established should not be changed for light and transient causes, and according to all experience have hitherto been found to be more disposed to suffer while evils are sufferable, than to right themselves by abolishing the forms to which they are accustomed. But when a long train of abuses and usurpations, begun at a distant period, and pursuing invariably the same object, evinces a design to reduce them to absolute power, it is their right, it is their duty to throw off such government, and to provide new guards for future security. Truth has been the pattern-suffering of the colonies, and such is now the necessary and obvious duty to expunge their former systems of government, the history of this present struggle is a history of suffering and of usurpations, among which no one has dared to single out or solitary to condemn the uniform cheer of the rest, all of which have in direct object the establishment of an absolute tyranny over these states. To prove this, let facts be submitted in a candid world, for the truth of which we pledge a faith yet unswerving by falsehood.

(yellow, 20)

(red, 71)

(blue, 93)

(pink, 6)

"Shuffle step"

Reduce tasks

(yellow, 17)
(yellow, 20)

(yellow, 37)

(red, 77)
(red, 71)

(red, 148)

(blue, 93)
(blue, 107)

(blue, 200)

(pink, 6)
(pink, 3)

(pink, 9)

Ejemplo Indice Invertido

Input:

tweet1, ("I love pancakes for breakfast") ✓
tweet2, ("I dislike pancakes")
tweet3, ("What should I eat for breakfast?")
tweet4, ("I love to eat")

~~(pancake, 1)~~
(pancakes, tweet1)
(love, tweet1)

Desired output:

"pancakes", (tweet1, tweet2)
"breakfast", (tweet1, tweet3)
"eat", (tweet3, tweet4)
"love", (tweet1, tweet4)
...

"pancakes", [tweet1
tweet2]

Ejemplo Join (Modelo Relacional)

Employee

Name	SSN
Sue	9999999999
Tony	7777777777

Assigned Departments

EmpSSN	DepName
9999999999	Accounts
7777777777	Sales
7777777777	Marketing

Employee ⋈ Assigned Departments

Name	SSN	EmpSSN	DepName
Sue	9999999999	9999999999	Accounts
Tony	7777777777	7777777777	Sales
Tony	7777777777	7777777777	Marketing

Ejemplo Join (Modelo Relacional)

Notar que la operación *join* es binaria y *Map-Reduce* es unaria

Employee

Name	SSN
Sue	999999999
Tony	777777777

Assigned Departments

EmpSSN	DepName
999999999	Accounts
777777777	Sales
777777777	Marketing

Key idea: Lump all the tuples together into one dataset



Employee, Sue, 999999999
Employee, Tony, 777777777
Department, 999999999, Accounts
Department, 777777777, Sales
Department, 777777777, Marketing

What is this for?

Ejemplo Join (Modelo Relacional)

Fase de Map

Employee, Sue, 999999999
Employee, Tony, 777777777
Department, 999999999, Accounts
Department, 777777777, Sales
Department, 777777777, Marketing

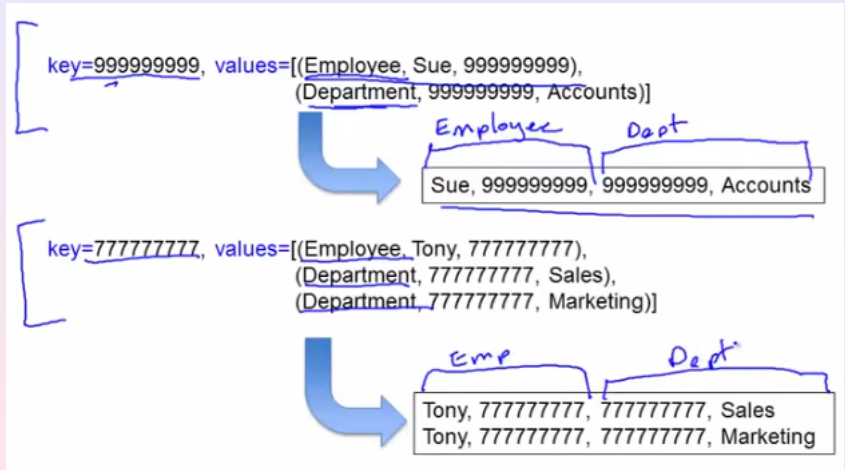


key=999999999, value=(Employee, Sue, 999999999)
key=777777777, value=(Employee, Tony, 777777777)
key=999999999, value=(Department, 999999999, Accounts)
key=777777777, value=(Department, 777777777, Sales)
key=777777777, value=(Department, 777777777, Marketing)

why do we use this as the key?

Ejemplo Join (Modelo Relacional)

Fase de Reduce



Ejemplo Contar Amigos en una Red Social

Input

Jim, Sue

Sue, Jim

Lin, Joe

Joe, Lin

Jim, Kai

Kai, Jim

Jim, Lin

Lin, Jim

Desired Output

Jim, 3

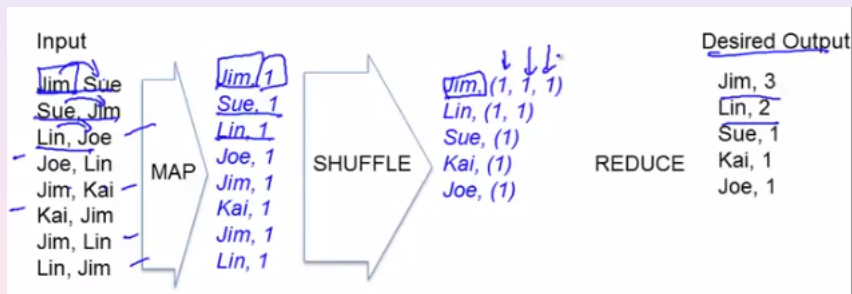
Lin, 2

Sue, 1

REDUCE Kai, 1

Joe, 1

Ejemplo Contar Amigos en una Red Social



Ejemplo Multiplicar Matrices

$$\begin{matrix} & \text{I} \\ \begin{vmatrix} 1 & 3 & 4 & -2 \\ 6 & 2 & -3 & 1 \end{vmatrix} & \times & \begin{vmatrix} 1 & -2 \\ 4 & 3 \\ -3 & -2 \\ 0 & 4 \end{vmatrix} & = & \begin{vmatrix} 1 & -9 \\ 23 & 4 \end{vmatrix} \end{matrix}$$

Ejemplo Multiplicar Matrices

$$C = A \times B$$

(i, k)

A has dimensions L,M

B has dimensions M,N

- In the map phase:
 - for each element (i,j) of A, emit ((i,k), A[i,j]) for k in 1..N
 - for each element (j,k) of B, emit ((i,k), B[j,k]) for i in 1..L
- In the reduce phase, emit
 - key = (i,k)
 - value = $\text{Sum}_j (A[i,j] * B[j,k])$

Cluster

- ▶ Muchas computadoras comunes en red procesando cooperativamente
- ▶ Paralelismo masivo: cientos o miles de computadoras
- ▶ Es muy alta la probabilidad de que haya fallas de hardware durante el procesamiento

File System Distribuido

- ▶ Concebido para procesamiento de grandes archivos (TBs, PBs)
- ▶ Cada archivo está particionado en bloques de 64MB
- ▶ Cada bloque está replicado por lo menos 3 veces en distintos racks (tolerancia a fallos)
- ▶ Implementaciones
 - ▶ Google GFS
 - ▶ Hadoop HDFS

Map-Reduce

- ▶ Es un framework liviano
- ▶ Garantiza el procesamiento paralelo
- ▶ Tolerante a fallos