Introduction to Data Management CSE 344

Lecture 29
Parallel Databases Wrap-up

Announcement

- Homework 8 (last) due on Friday night
  - Please read Daseul's updates
- Friday: last lecture
  - Final review
- Next Wednesday: final exam

A Challenge

- Have P servers (say P=27 or P=1000)
- How do we compute this query?
  $Q(x,y,z) = R(x,y),S(y,z),T(z,x)$

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- This computes all "triangles".
- E.g. let Follows(x,y) be all pairs of Twitter users s.t. x follows y. Let R=S=T=Follows. Then Q computes all triples of people that follow each other.

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  - Each server sends R(x,y) to server h(y) mod P
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- Step 2:
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  – Each server sends [R(x,y),S(y,z)] to h(x) mod P
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- Final output:
  - Each server computes locally and outputs $R \bowtie S \bowtie T$

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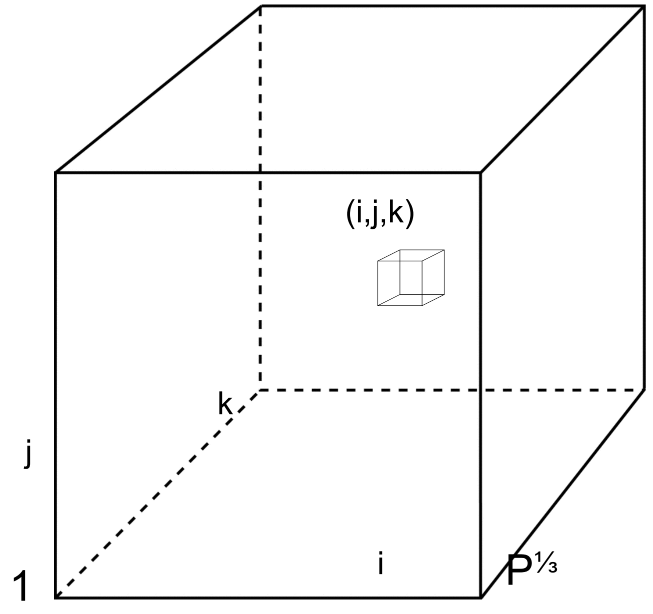
  Q(x,y,z) = R(x,y),S(y,z),T(z,x)
- Organize the P servers into a cube with side $P^{1/3}$
  - Thus, each server is uniquely identified by (i,j,k), $i,j,k \le P^{1/3}$



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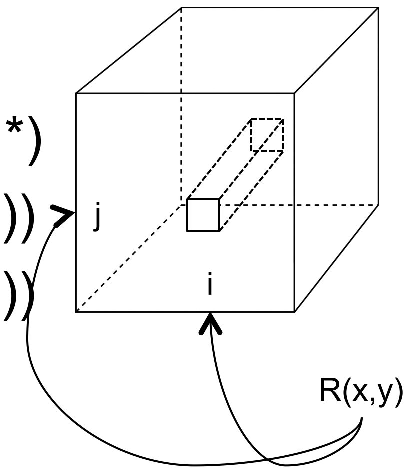

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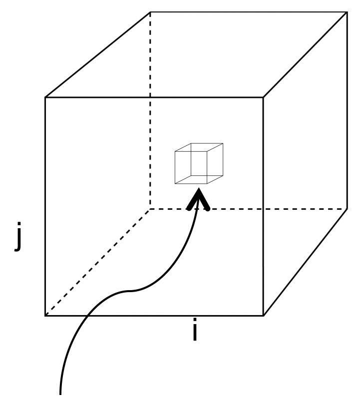

- Final output:
  - Each server (i,j,k) computes the query R(x,y),S(y,z),T(z,x) locally

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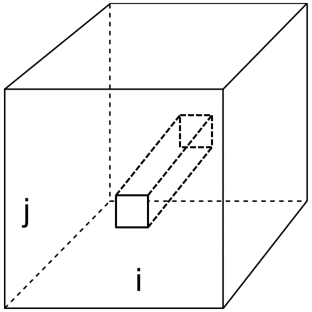


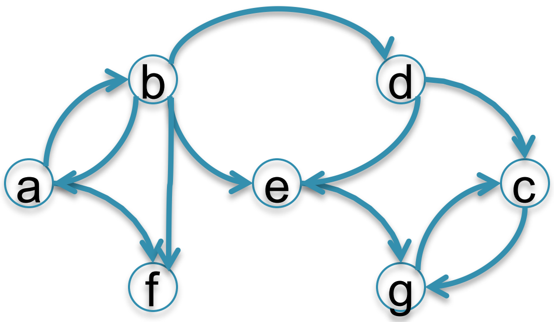
- Final output:
  - Each server (i,j,k) computes the query R(x,y),S(y,z),T(z,x) locally
- Analysis: each tuple R(x,y) is replicated at most $P^{1/3}$ times

Graph Analysis in HW8

Graph Databases

Many large databases are graphs

- Give examples in class

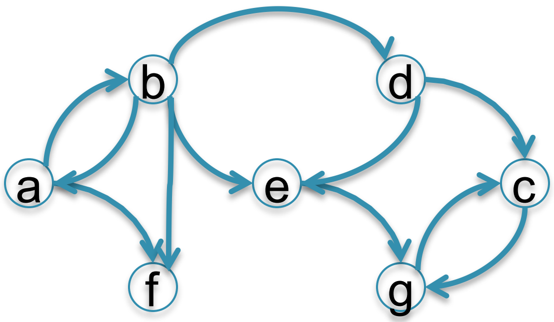


Source	Target
a	b
b	a
a	f
b	f
b	e
b	d
d	e
d	c
e	g
g	c
c	g

Graph Databases

Many large databases are graphs

- Give examples in class
- The Web
- The Internet
- Social Networks
- Flights between airports
- Etc.



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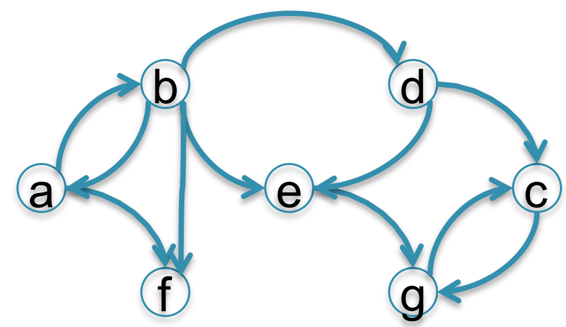
Data Analytics on Big Graphs

Queries expressible in SQL:

- How many nodes (edges)?
- How many nodes have > 4 neighbors?
- Which are “most connected nodes”?

Queries requiring recursion:

- Is the graph connected?
- What is the diameter of the graph?
- Compute *PageRank*
- Compute the *Centrality* of each node



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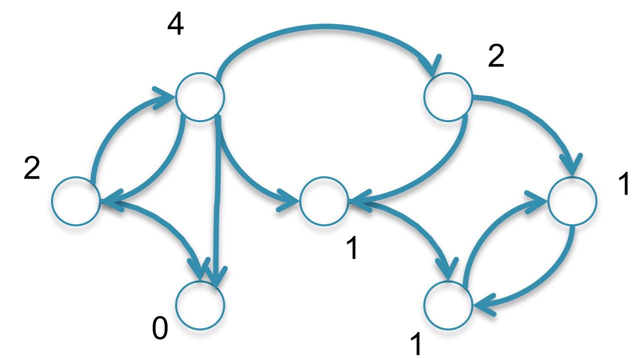
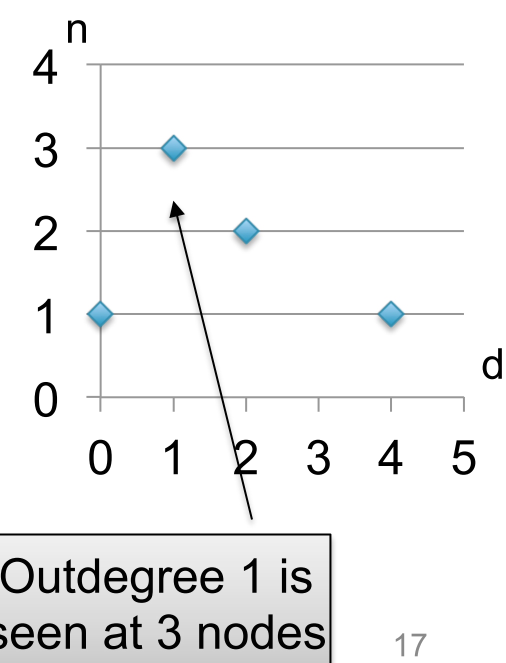
Example: the Histogram of a Graph

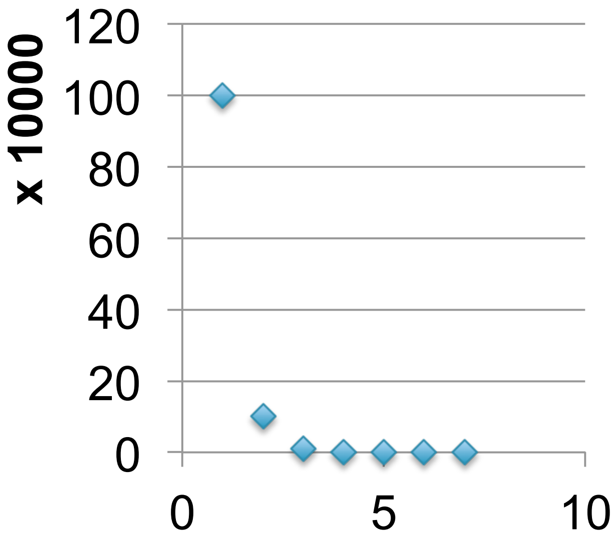
- Outdegree of a node = number of outgoing edges
- For each d, let n(d) = number of nodes with oudegree d
- The outdegree histogram of a graph = the scatterplot (d, n(d))

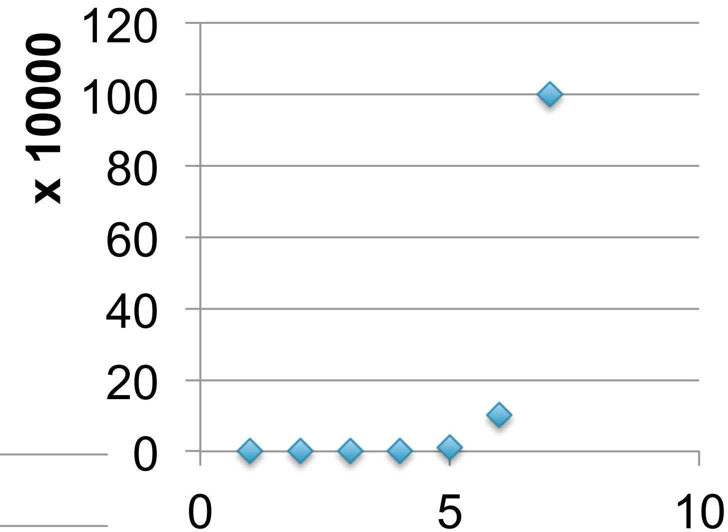


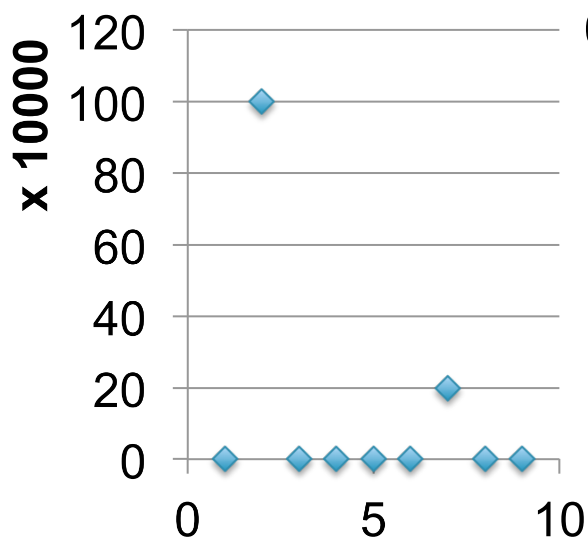
d	n(d)
0	1
1	3
2	2
3	0
4	1



Histograms Tell Us Something About the Graph





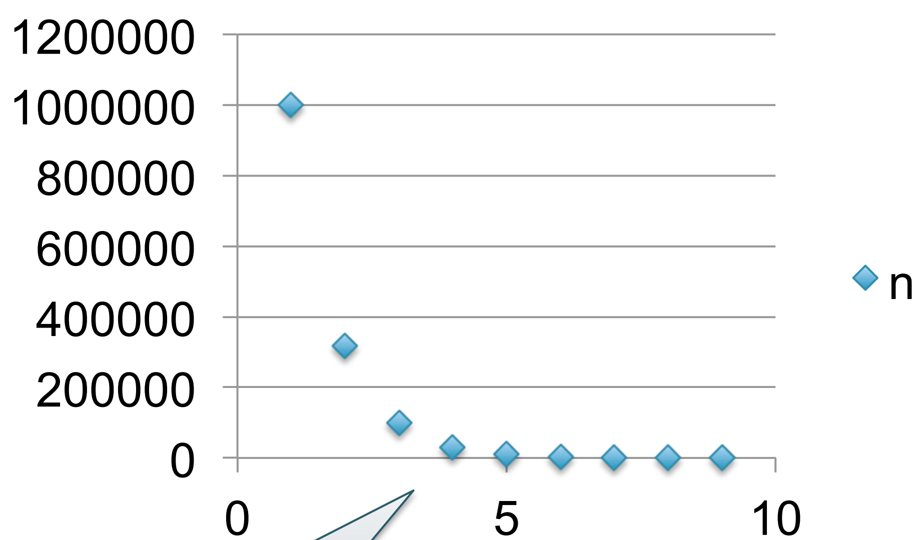


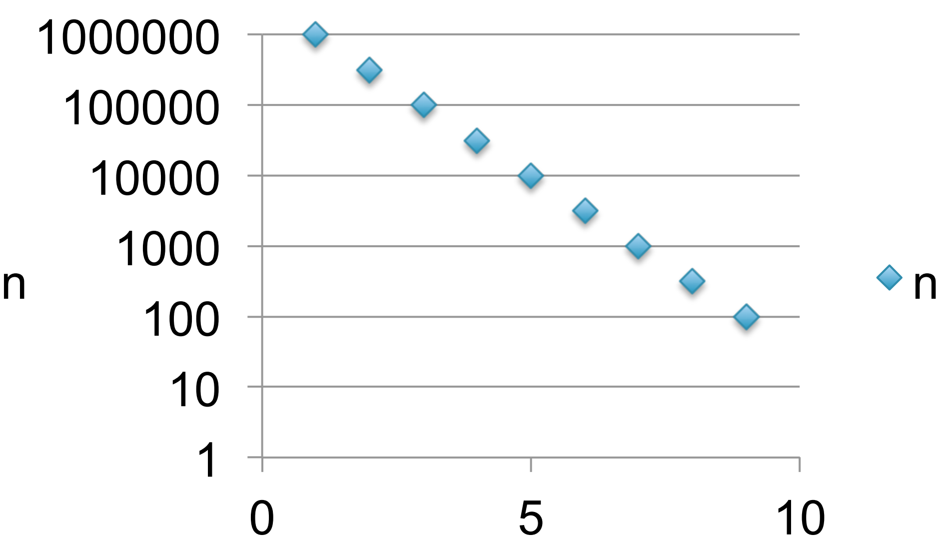
What can you say about these graphs?

Exponential Distribution

nodes with degree d

- $n(d) \cong c/2^d$ (generally, cx^d, for some $x < 1$)
- A *random graph* has exponential distribution
- Best seen when n is on a log scale

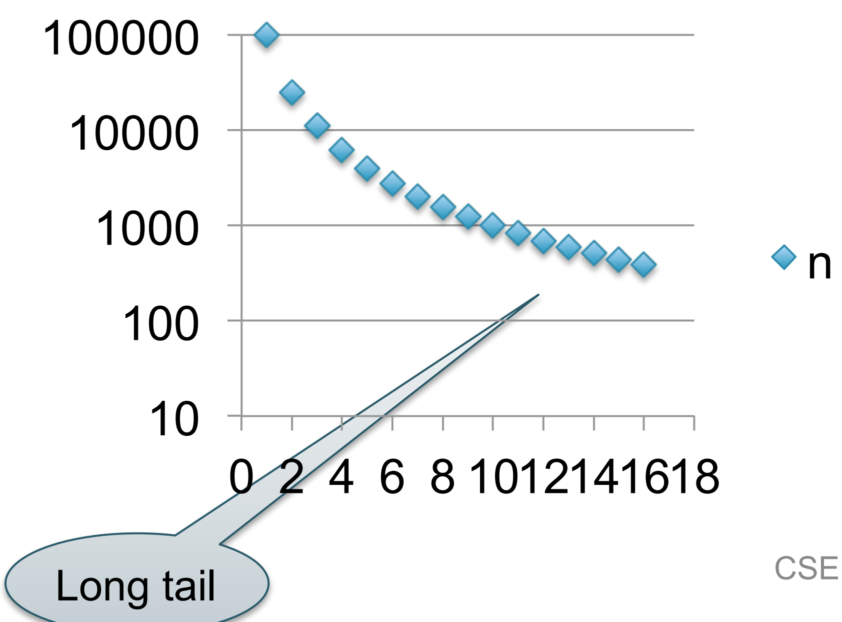


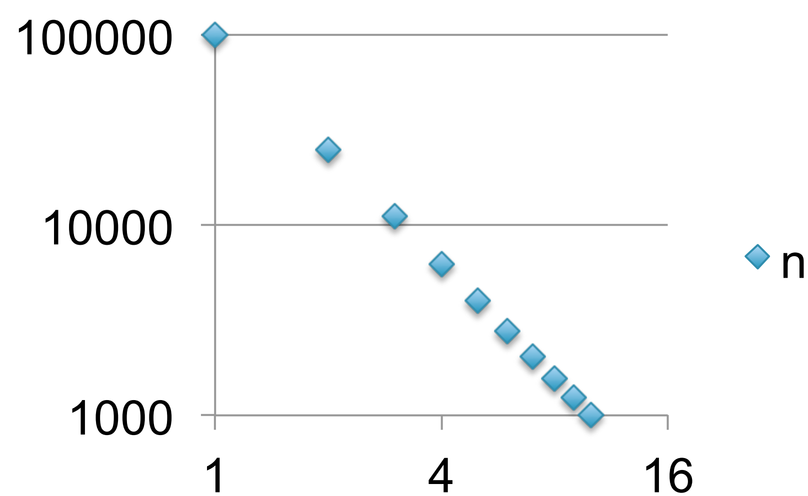


Quickly vanishing

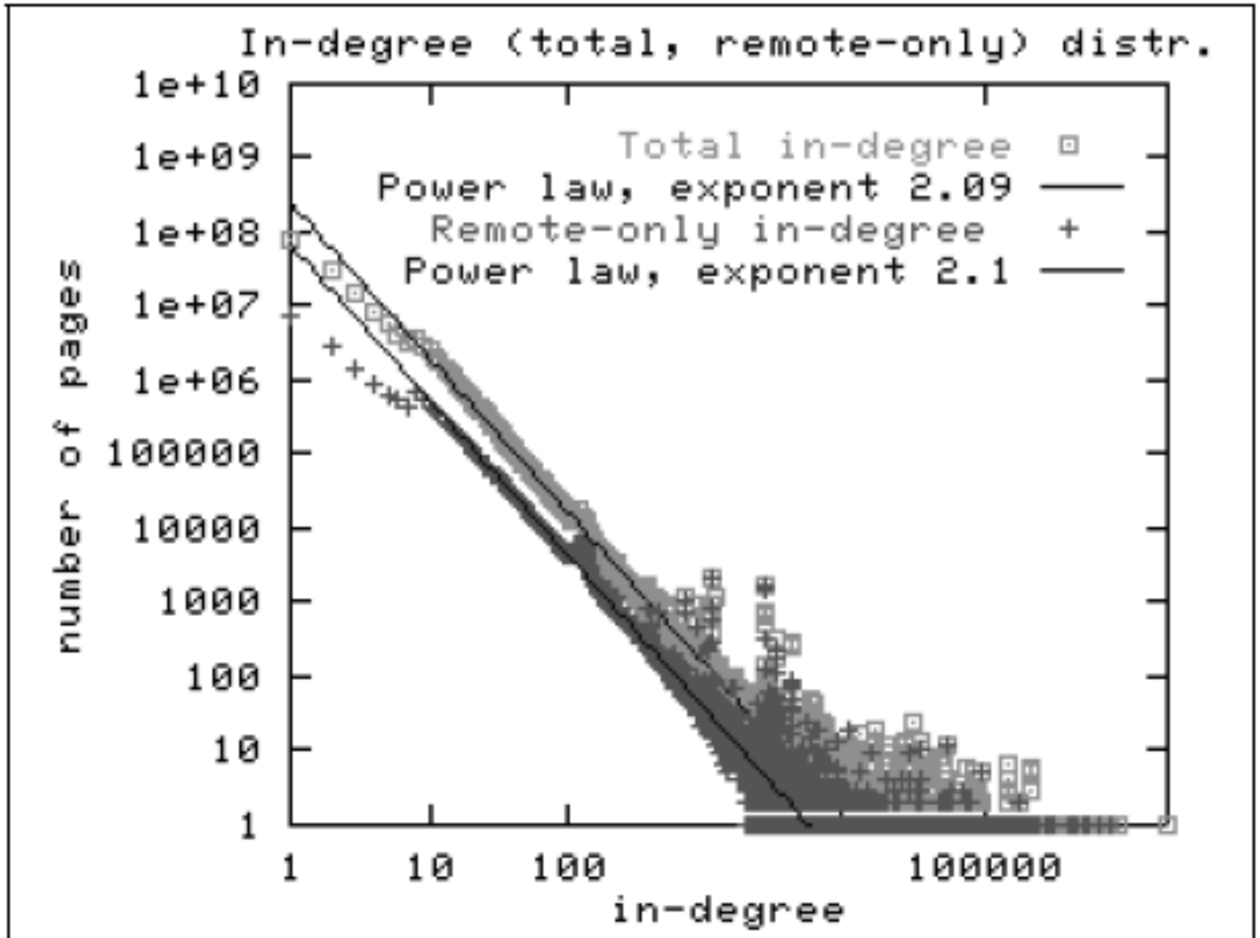
Power Law Distribution (Zipf)

- $n(d) \cong 1/d^x$, for some value $x>0$
- Human-generated data follows power law: letters in alphabet, words in vocabulary, etc.
- Best seen in a log-log scale





The Histogram of the Web



Late 1990's
200M Webpages

Exponential ?

Power Law?

Figure 2: In-degree distribution.

The Bowtie Structure of the Web

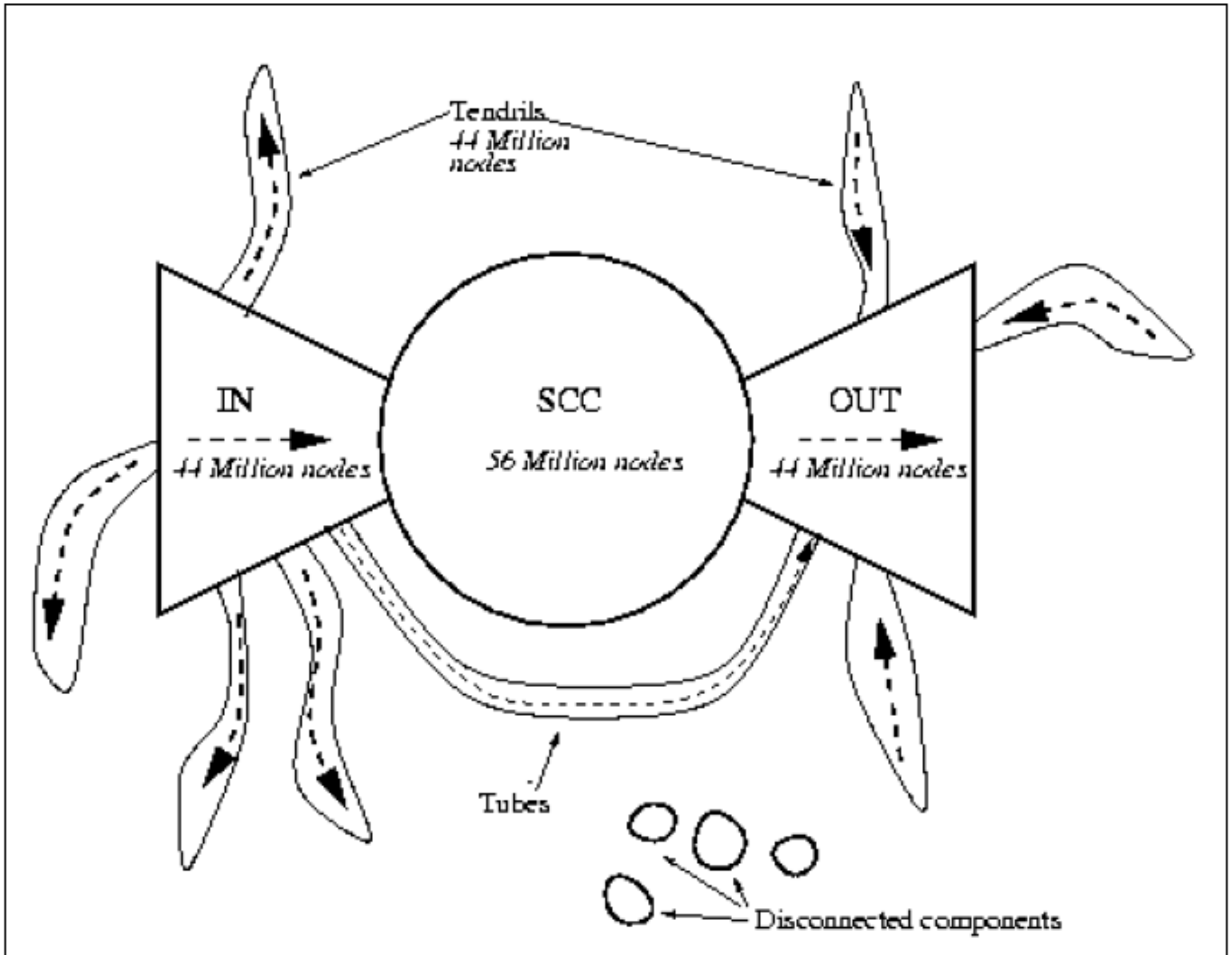


Figure 4: The web as a bowtie. SCC is a giant strongly connected component. IN consists of pages with paths to SCC, but no path from SCC. OUT consists of pages with paths from SCC, but no path to SCC. TENDRILS consists of pages that cannot surf to SCC, and which cannot be reached by surfing from SCC.

users(name, age)
pages(user, url)

Hash Join in MapReduce

```
Users = load 'users' as (name, age);
Pages = load 'pages' as (user, url);
Jnd = join Users by name, Pages by user;
```

```
Map(String value):
    // value.relation is either 'Users' or 'Pages'
    if value.relation='Users':
     EmitIntermediate(value.name, (1, value));
    else
     EmitIntermediate(value.user, (2, value));
```

```
reduce(String k, Iterator values):
    Users = empty;  Pages = empty;
    for each v in values:
     if v.type = 1: Users.insert(v)
      else Pages.insert(v);
    for v1 in Users, for v2 in Pages
     Emit(v1,v2);
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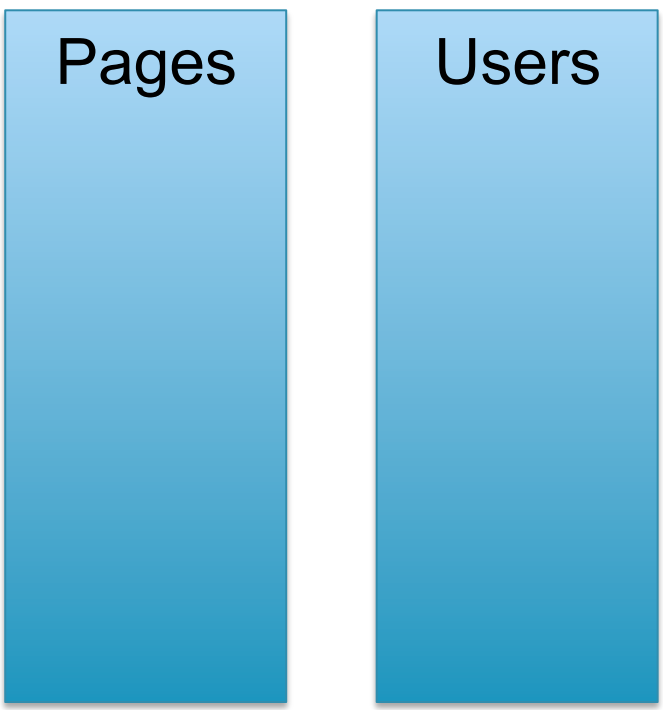

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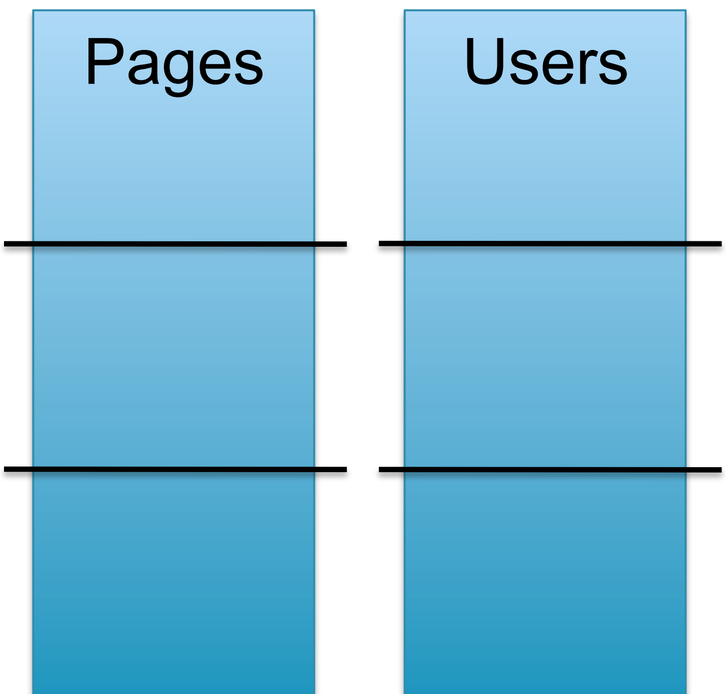

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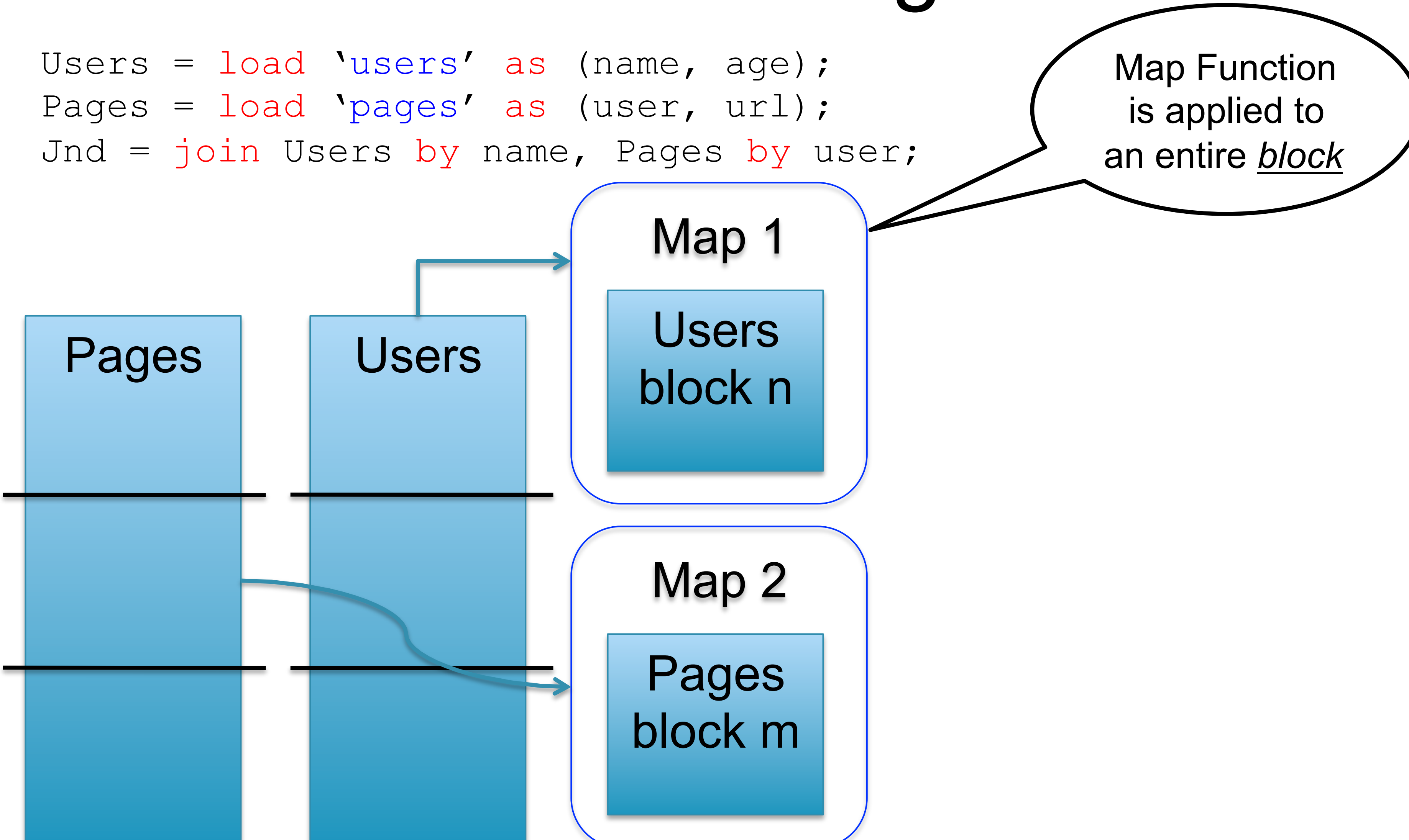

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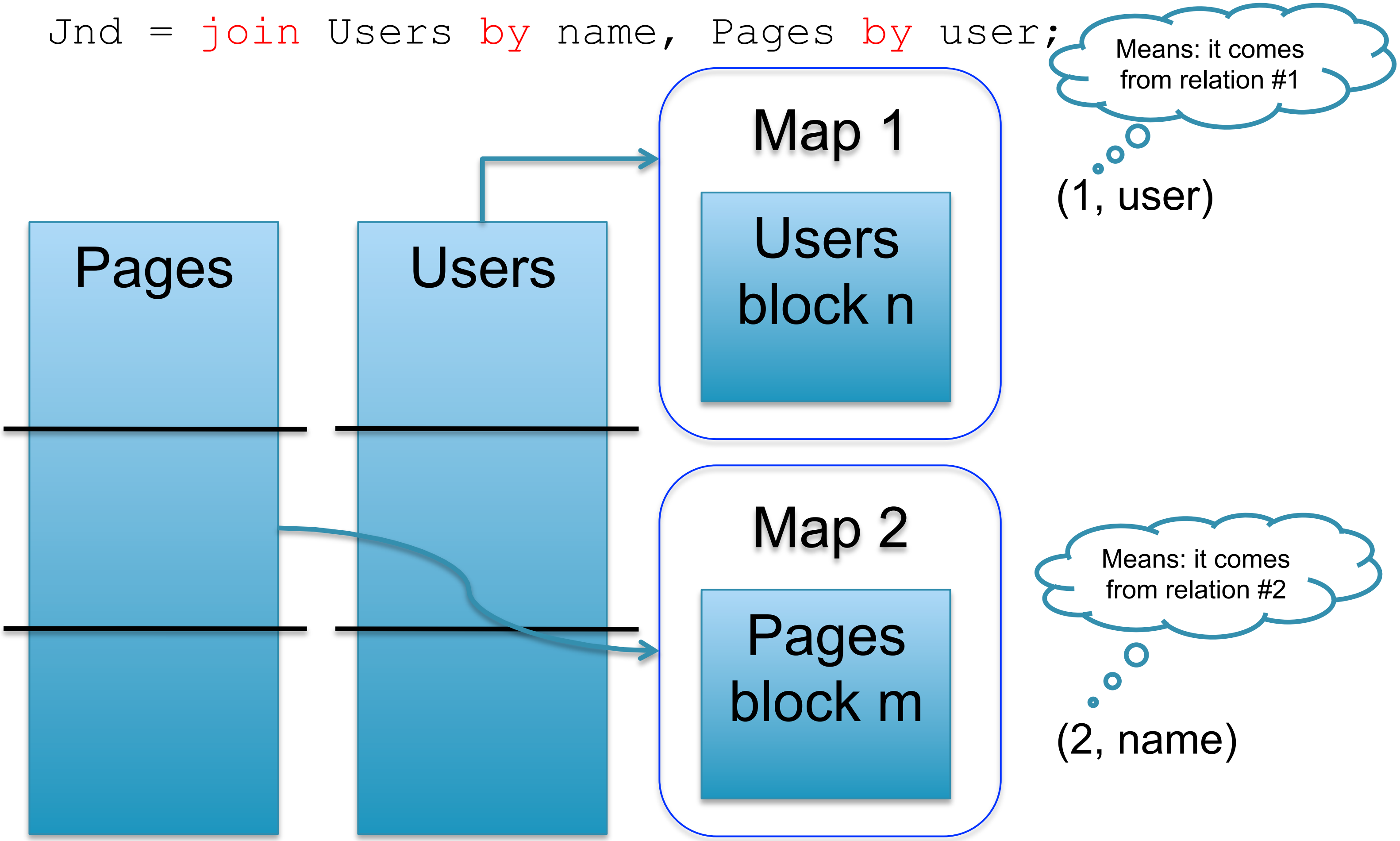

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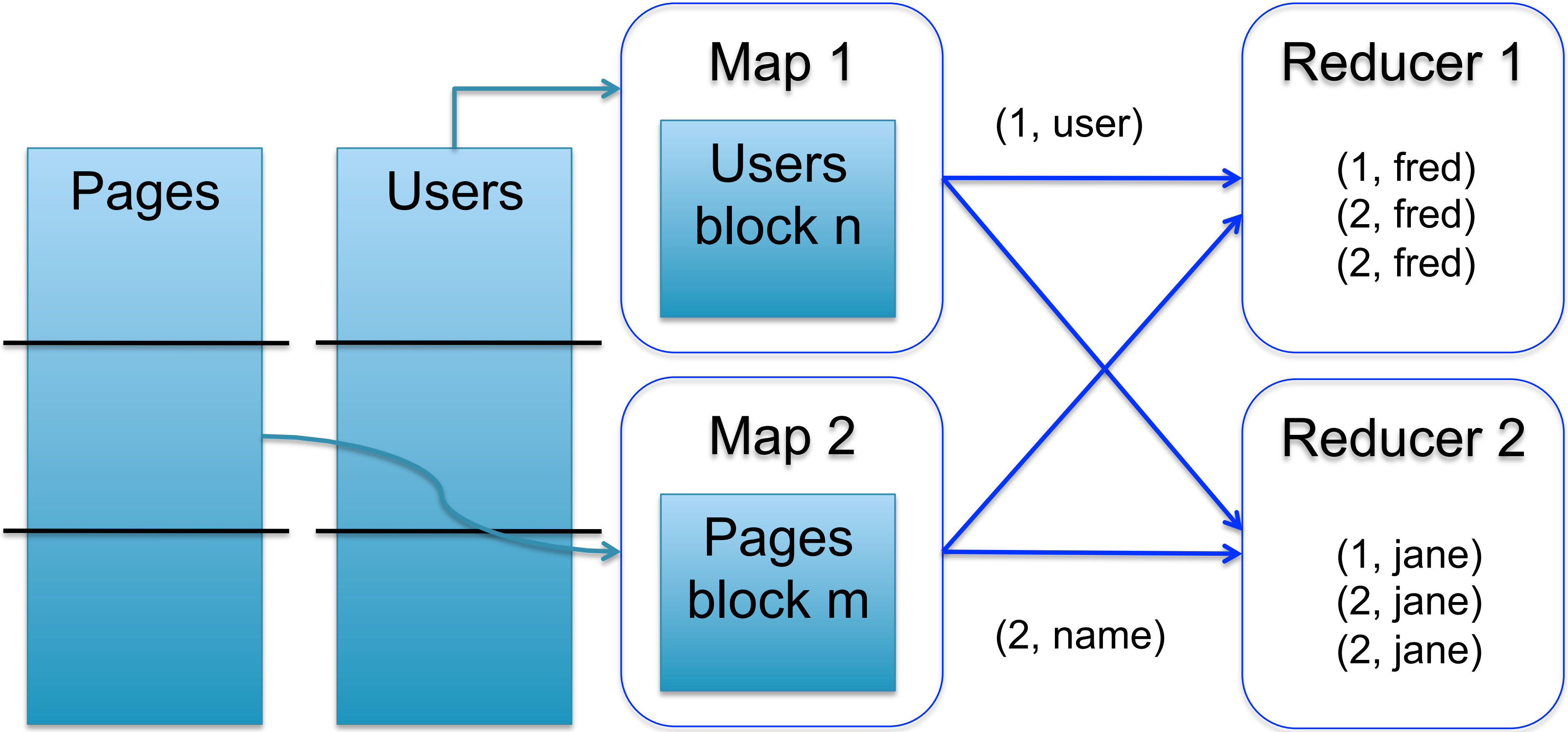

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Broadcast Join

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Users = load 'users' as (name, age);
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Jnd = join Pages by user, Users by name using "replicated";
```

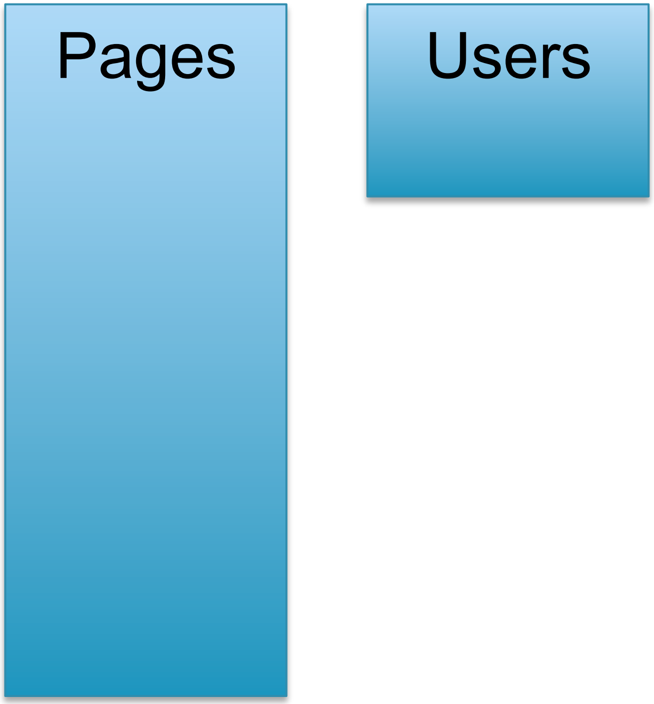

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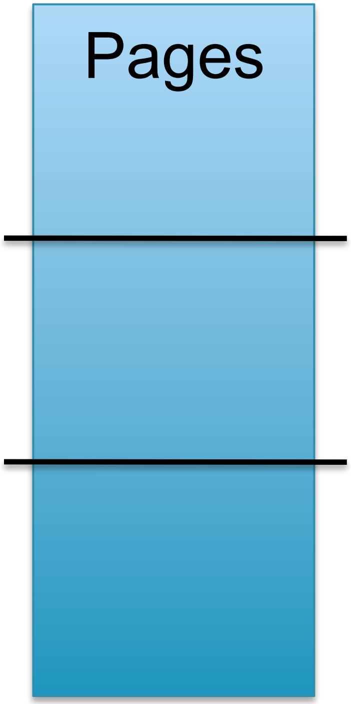

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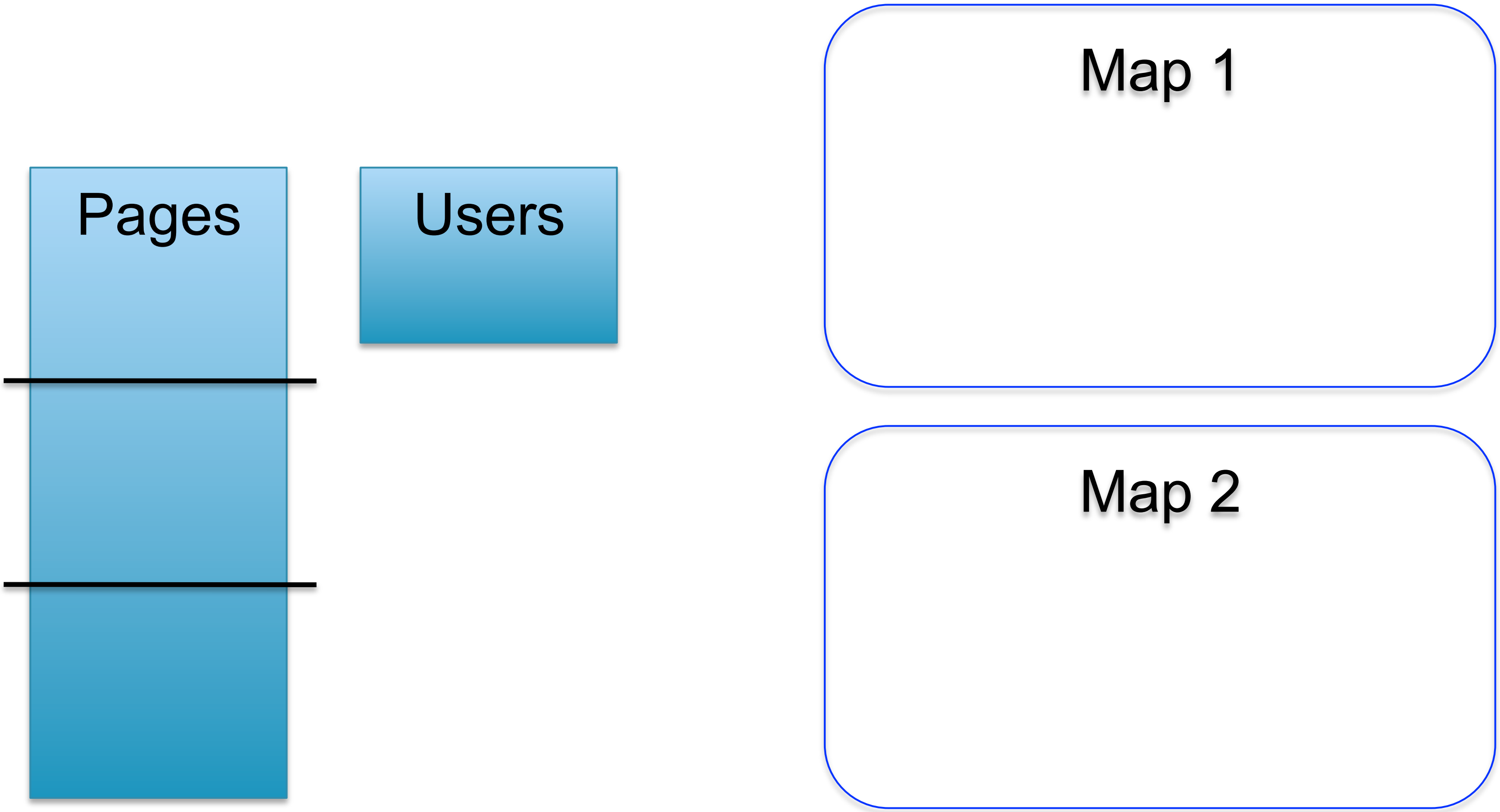

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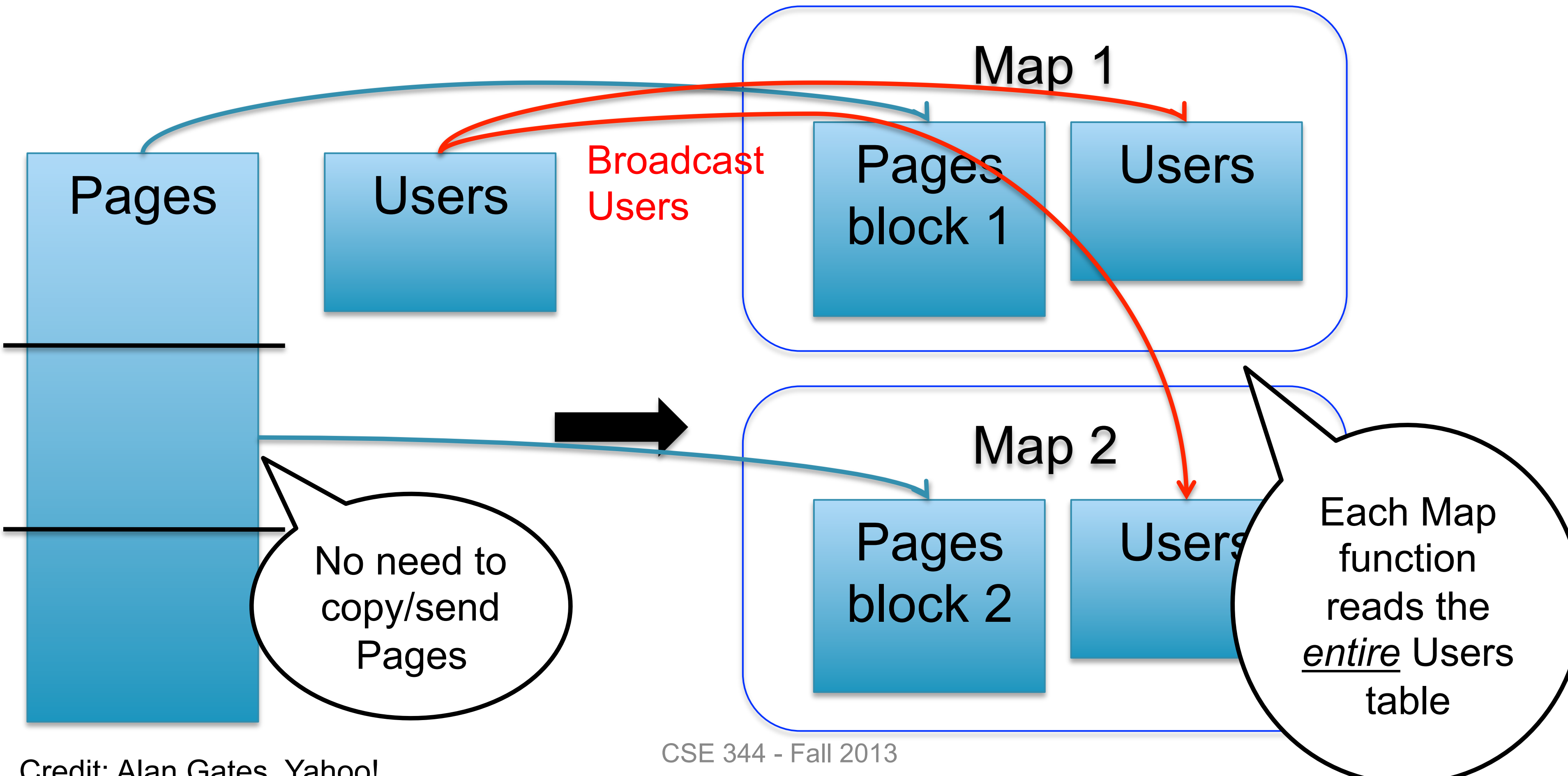

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Matrix Multiplication v.s. Join

Dense matrices:

$$\begin{bmatrix} 6 & 6 & 0 \\ 1 & 0 & 0 \\ 2 & 0 & 6 \end{bmatrix} = \begin{bmatrix} 0 & 3 & 3 \\ 1 & 0 & 0 \\ 2 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 3 \\ 0 & 2 & 0 \\ 2 & 0 & 0 \end{bmatrix}$$

forall i,k **do**
    $C[i,k] = \Sigma_j A[i,j] * B[j,k]$

Matrix Multiplication v.s. Join

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Sparse matrices as relations:

B(j,k,v)

j	k	v
1	1	1
1	3	3
2	2	1
3	1	2

A(i,j,v)

i	j	v
1	2	3
1	3	3
2	1	1
3	1	2

```
SELECT A.i, B.k, sum(A.v*B.v)
FROM A, B
WHERE A.j=B.j
GROUP BY A.i,B.i
```

Matrix Multiplication v.s. Join

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Matrix multiplication = a join + a group by

Parallel DBs v.s. MapReduce

Parallel DB

- Plusses

- Minuses

MapReduce

- Minuses

- Plusses

Parallel DBs v.s. MapReduce

Parallel DB

- Plusses
  - Efficient binary format
  - Indexes, physical tuning
  - Cost-based optimization
- Minuses
  - Difficult to import data
  - Lots of baggage: logging, transactions

MapReduce

- Minuses
  - Lots of time spent parsing!
  - Text files
  - "Optimizers is between your eyes and your keyboard"
- Plusses
  - Any data
  - Lightweight, easy to speedup
  - Arguably more scalable