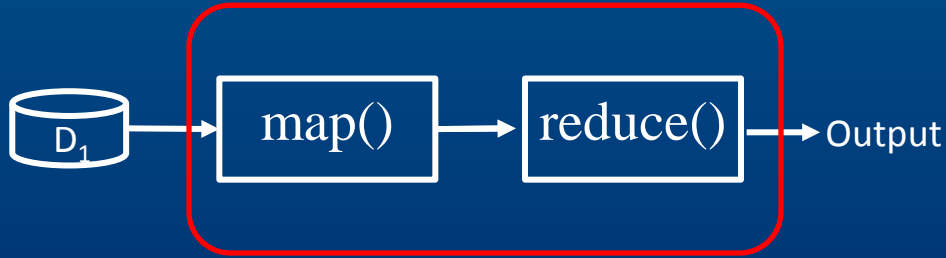


Introduction to Map/Reduce

Examples and Principles

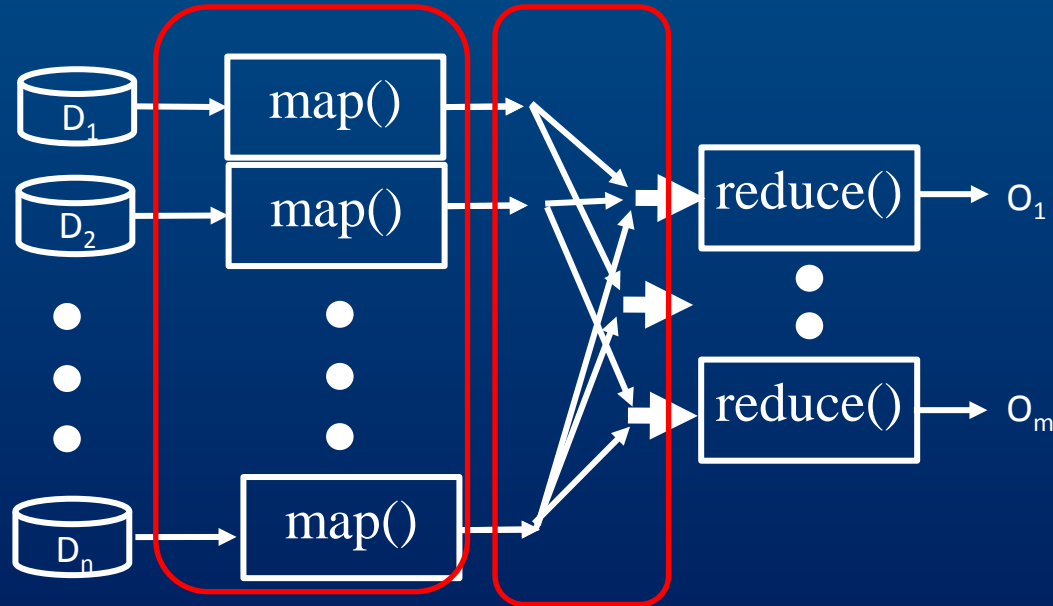
Recall the framework:

- User defines $\langle \text{key}, \text{value} \rangle$, mapper, and reducer



Recall the framework:

- Hadoop handles the logistics



Hadoop Rule of Thumb

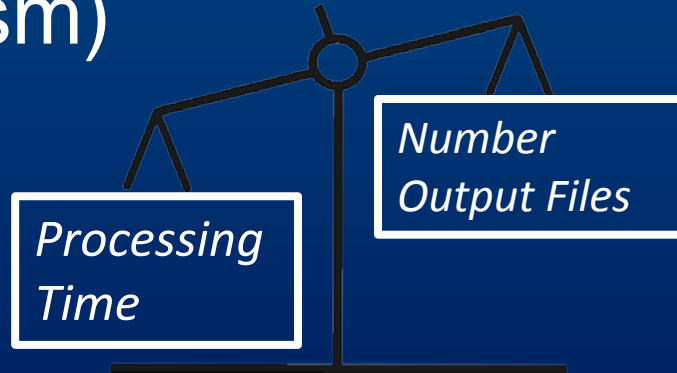
- 1 mapper per data split (typically)

Hadoop Rule of Thumb

- 1 mapper per data split (typically)
- 1 reducer per computer core (best parallelism)

Hadoop Rule of Thumb

- 1 mapper per data split (typically)
- 1 reducer per computer core (best parallelism)

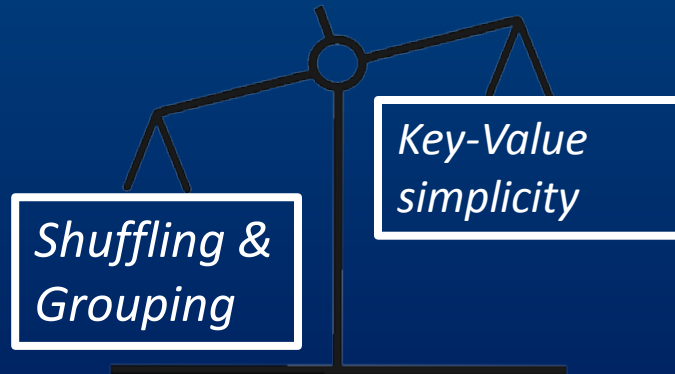


Wordcount Strategy

- Let $\langle \text{word}, 1 \rangle$ be the $\langle \text{key}, \text{value} \rangle$
- Simple mapper & reducer
- Hadoop did the hard work of shuffling & grouping

Good key-value properties

- Simple
- Enables reducers to get correct output



Good Task Decomposition:

Mappers: simple and separable



Reducers: easy consolidation



Example: Trending Wordcount

Trending Wordcount

- Twitter Data: date, message, location, ... [other metadata]

Trending Wordcount

- Twitter Data: date, message, location, ... [other metadata]

Task 1 Get word count by day

Task 2 Get total word count

Trending Wordcount

Task 1: get word count by day

Trending Wordcount

Task 1: get word count by day

Design: *Use composite key*

Map/Reduce: `<date word,count>`

Trending Wordcount

Task 2: get total word count

Trending Wordcount

Task 2: get total word count

Easy way:

re-use previous wordcount

Trending Wordcount

Task 2: get total word count

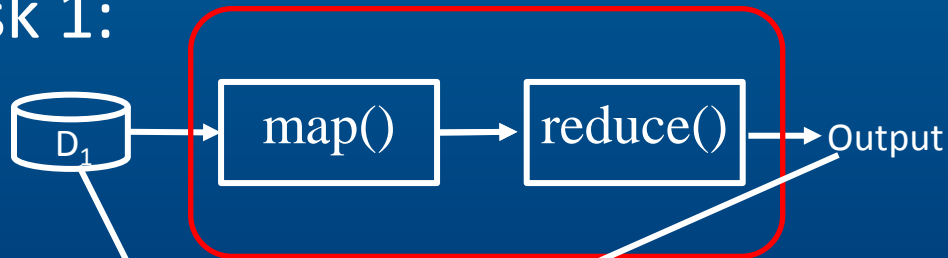
Alternatively:

use Task 1 output

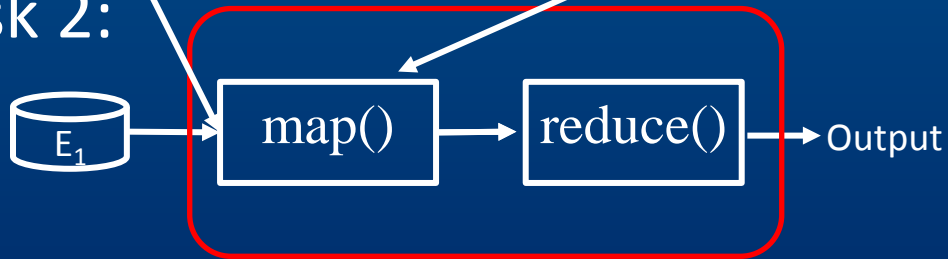
(it's partially aggregated)

Cascading Map/Reduce

Task 1:



Task 2:



Task 3 ...

Example: Joining Data

Joining Data

- Task: combine datasets by key
 - A standard data management function

Joining Data

- Task: combine datasets by key
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 - In pseudo SQL
 - Select * from table A, table B, where
A.key=B.key

Joining Data

- Task: combine datasets by key
 - A standard data management function
 - In pseudo SQL
 - Select * from table A, table B, where
A.key=B.key
 - Joins can be inner, left or right outer

Joining Data

- Task: given two wordcount datasets ...

Joining Data

- Task: given two wordcount datasets ...

File A: <word, total-count>

able , 5

actor , 18

burger , 25

•

•

•

Joining Data

- Task: given two wordcount datasets ...

File A: <word, total-count> File B: <date word, day-count>

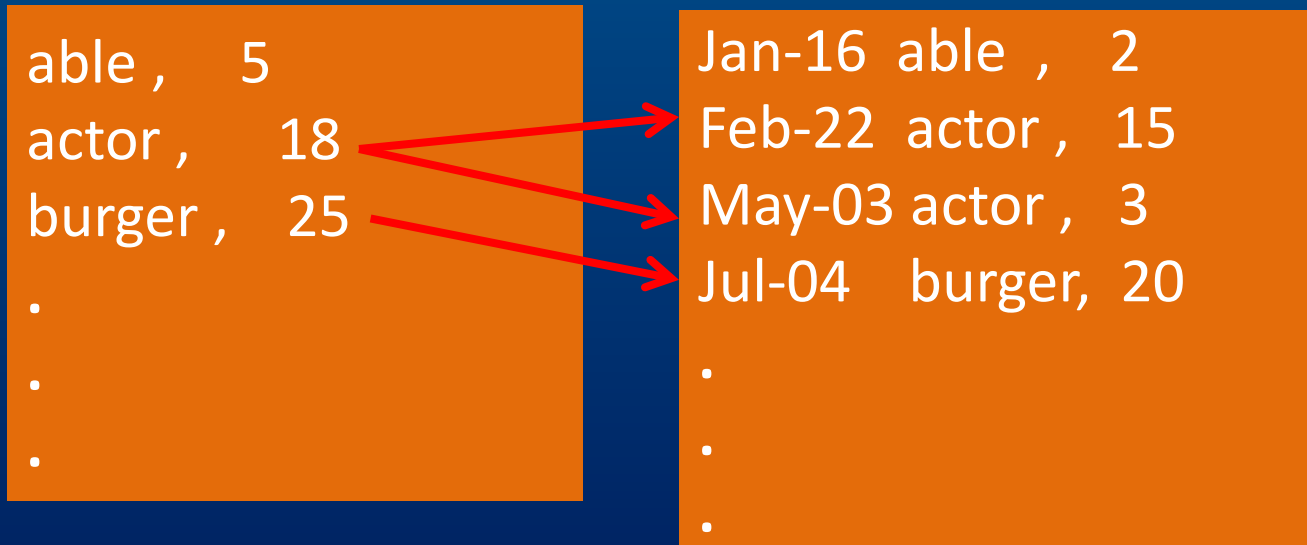
```
able , 5
actor , 18
burger , 25
.
.
.
```

```
Jan-16 able , 2
Feb-22 actor , 15
May-03 actor , 3
Jul-4 burger, 20
.
.
.
```

Joining Data

- Task: combine by word

File A: <word, total-count> File B: <date word, day-count>



Joining Data

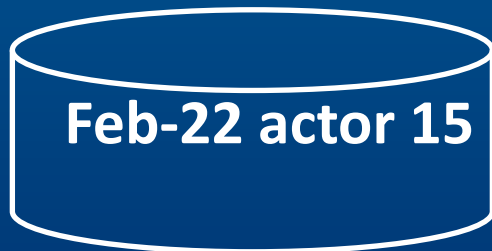
- Result wanted:

File AjoinB: <word date, day-count total-count >

```
able Jan-16, 2 5
actor Feb-22, 15 18
actor May-03, 1 18
burger Jul-04, 20 25
.
.
.
```

Joining Data

- Recall that data is split in parts



*How to gather
the right pieces?*

Key-Value & Task Decomposition

- Main design consideration:

Join depends on word

*(e.g. Select * where A.word=B.word)*

Key-Value & Task Decomposition

- For the join:
 - Let <key> = word
 - Let <value> = other info

<word, ... >

Key-Value & Task Decomposition

- Note:

File A: <word, total-count>

```
able , 5  
actor , 18  
...
```

File B: <date word, day-count>

```
Jan-16 able , 2  
Feb-22 actor , 15  
...
```

Key-Value & Task Decomposition

- Note:

File A: <word, total-count>

```
able , 5  
actor , 18  
...
```

File B: <date word, day-count>

```
Jan-16 able , 2  
Feb-22 actor , 15  
...
```

word already the key

Key-Value & Task Decomposition

- Note:

File A: <word, total-count>

```
able , 5
actor , 18
...
```

File B: <date word, day-count>

```
Jan-16 able , 2
Feb-22 actor , 15
...
```

date needs to be filtered out

Key-Value & Task Decomposition

- Note:

File A: <word, total-count>

```
able , 5
actor , 18
...
```

File B: <date word, day-count>

```
Jan-16 able , 2
Feb-22 actor , 15
...
```

date needs to be filtered out
Where should date info go?

Key-Value & Task Decomposition

<word, date day-count total-count >



put date into value field

Task Decomposition

- Now data sets are:

File A: <word, total-count> File B_new: <word, date count>

```
able ,    5
actor ,   18
burger ,  25
.
```

```
able , Jan 16  2
actor , Feb-22 15
actor , May-03  3
burger , Jul-04 20
.
```

Task Decomposition

- How will Hadoop shuffle & group these?

File A: <word, total-count> File B_new: <word, date day-count>

```
able ,    5
actor ,  18
burger , 25
.
```

```
able , Jan-16  2
actor , Feb-22 15
actor , May-03  3
burger , Jul-04 20
.
```

Task Decomposition

- How will Hadoop shuffle & group these?

Let's focus on 1 key:

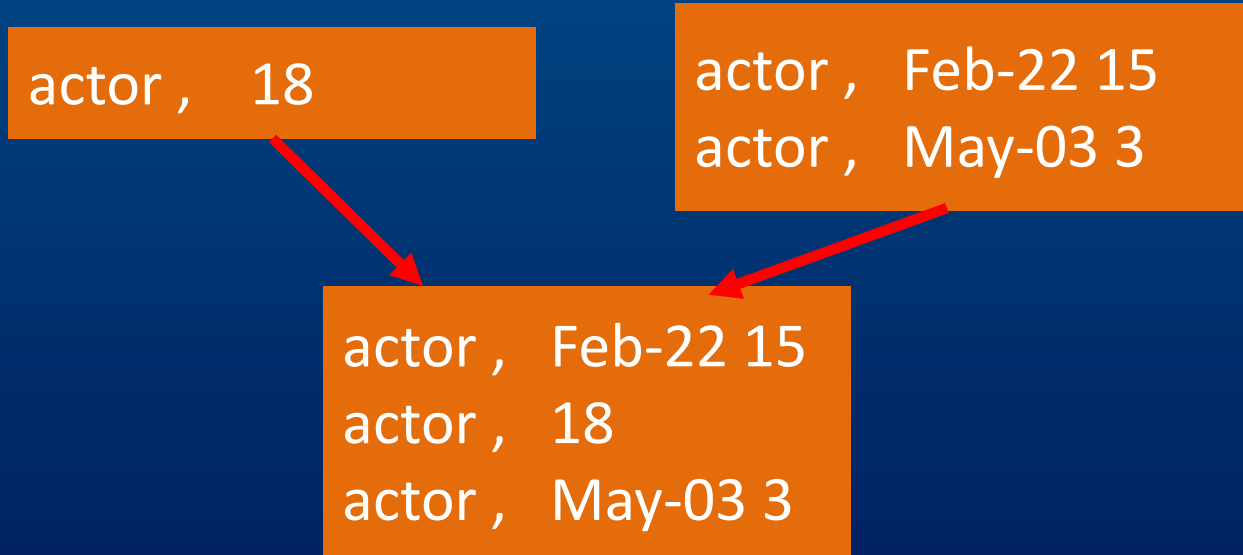
actor , 18

actor , Feb-22 15

actor , May-03 3

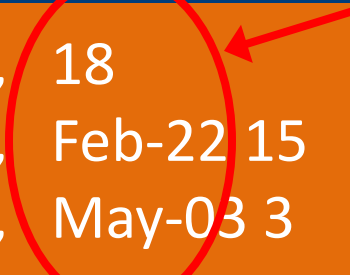
Task Decomposition

- Hadoop gathers the data for a join



Task Decomposition

- Reducer now has all the data for same word grouped together

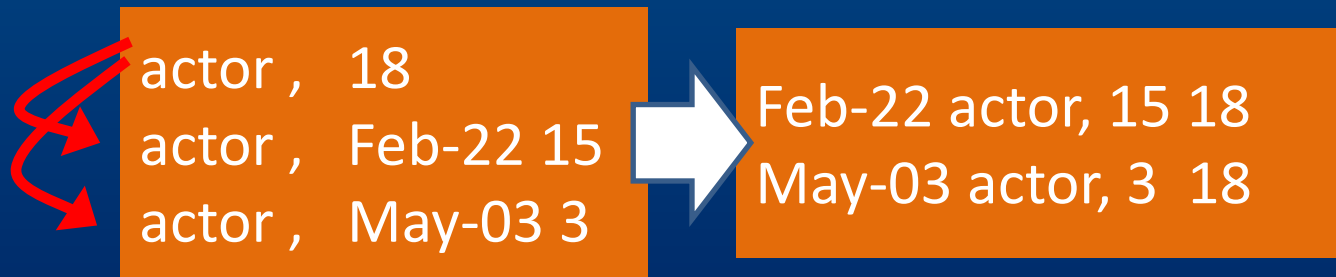


```
actor , 18
actor , Feb-22 15
actor , May-03 3
```

*A number or date
indicates file source*

Task Decomposition

- Reducer can now join the data and put date back into key



Example: Vector Multiplication

Vector Multiplication

- Task: multiply 2 arrays of N numbers
 - A basic mathematical operation
 - Let's assume N is very large

Vector Multiplication

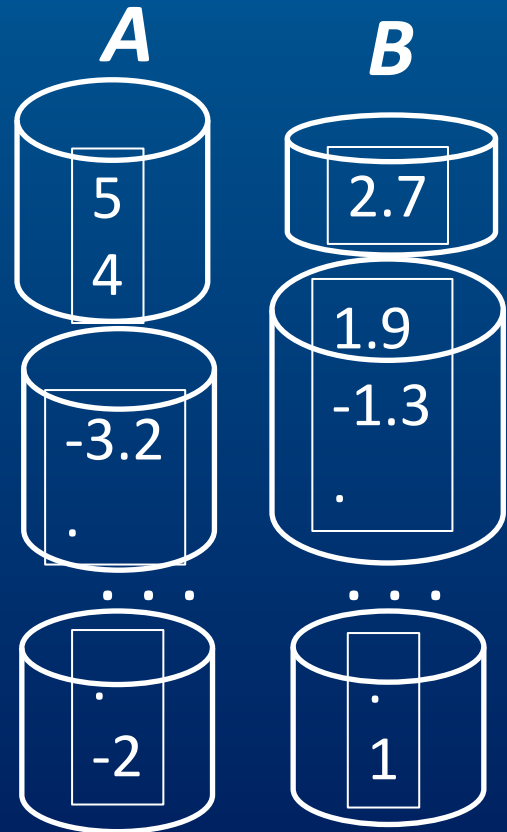
- Task: multiply 2 arrays of N numbers

$$\begin{array}{c} \mathbf{A} \\ \hline 5 \\ 4 \\ -3.2 \\ \cdot \\ \cdot \\ \cdot \\ -2 \end{array} \times \begin{array}{c} \mathbf{B} \\ \hline 2.7 \\ 1.9 \\ -1.3 \\ \cdot \\ \cdot \\ \cdot \\ 1 \end{array}$$



$$\begin{aligned} &= \\ &\quad (5 \times 2.7) \quad \# \text{ 1}^{\text{st}} \text{ of } A \ \& \ B \\ &+ (4 \times 1.9) \quad \# \text{ 2}^{\text{nd}} \text{ of } A \ \& \ B \\ &+ (-3.2 \times -1.3) \quad \# \text{ 3}^{\text{rd}} \dots \\ &\cdot \\ &\cdot \\ &\cdot \\ &+ (-2 \times 1) \quad \# \text{ Nth of } A \ \& \ B \end{aligned}$$

Vector Multiplication



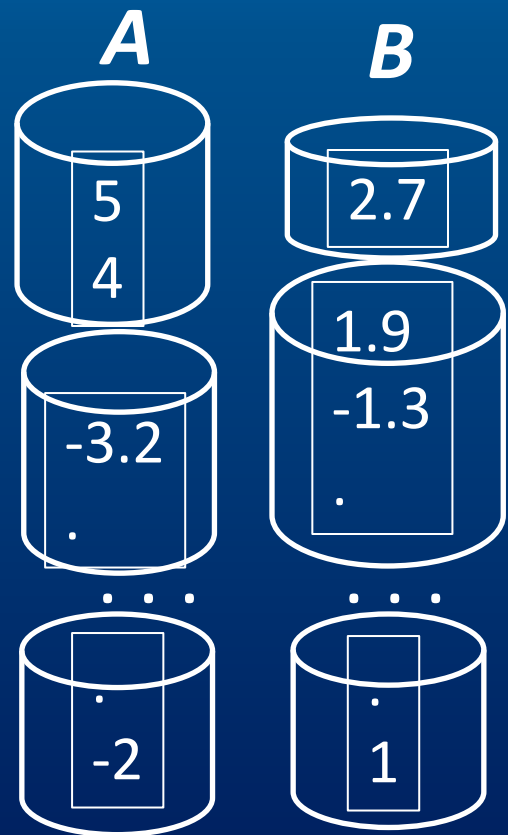
- Recall:
 - data partitioned in HDFS

Vector Multiplication

- Main design consideration:
need elements with same index together

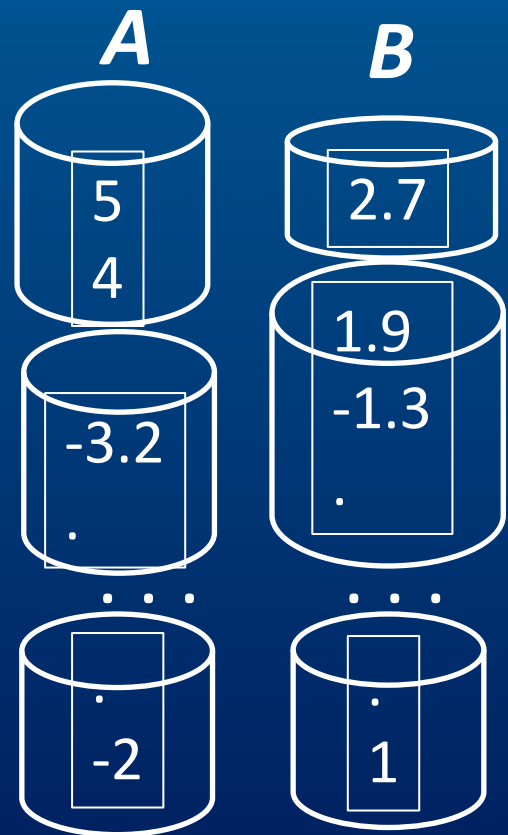
Let $\langle \text{key}, \text{value} \rangle =$
 $\langle \text{index}, \text{number} \rangle$

Vector Multiplication



- Problem: array partitions don't have an index

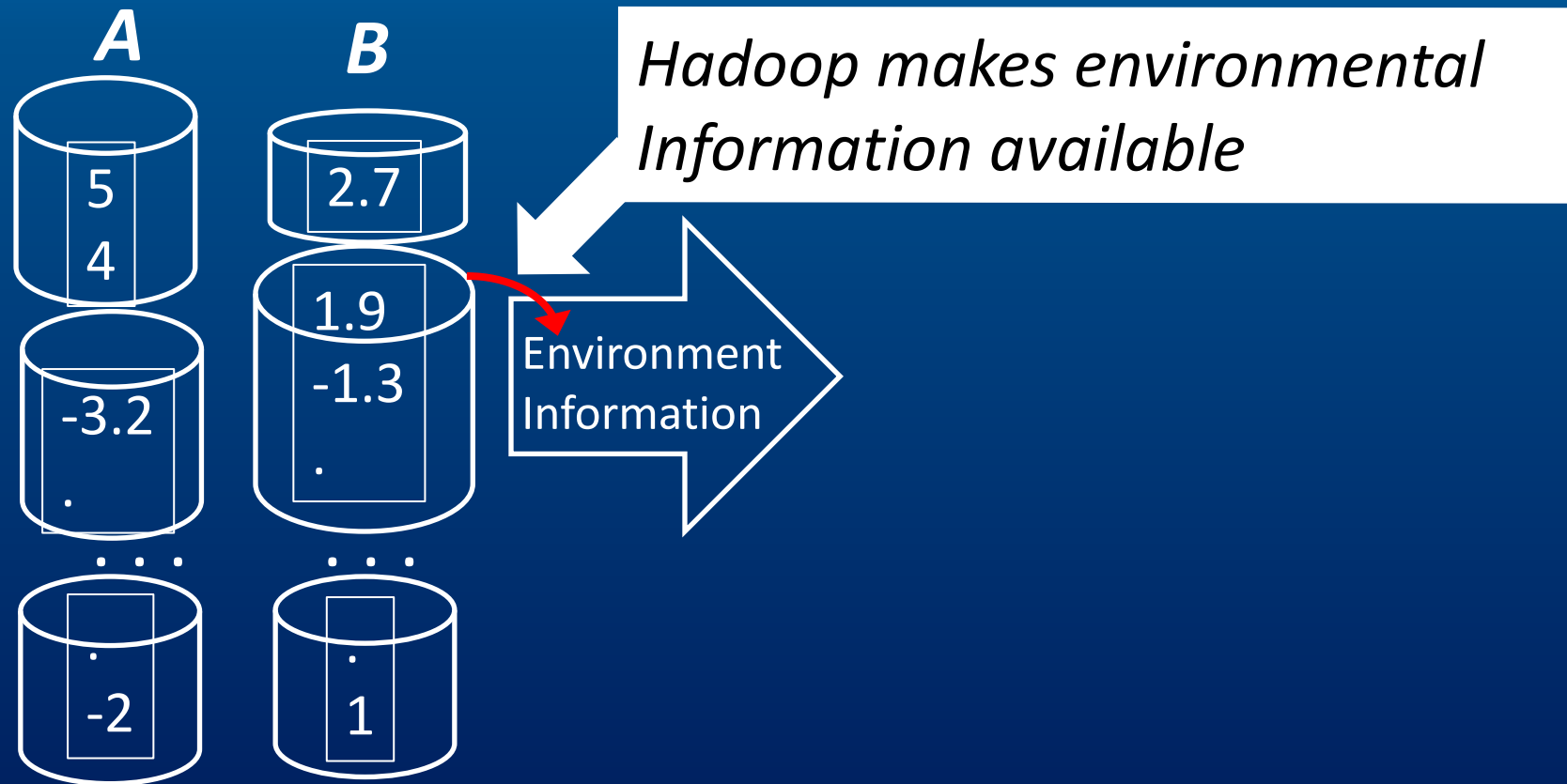
Vector Multiplication



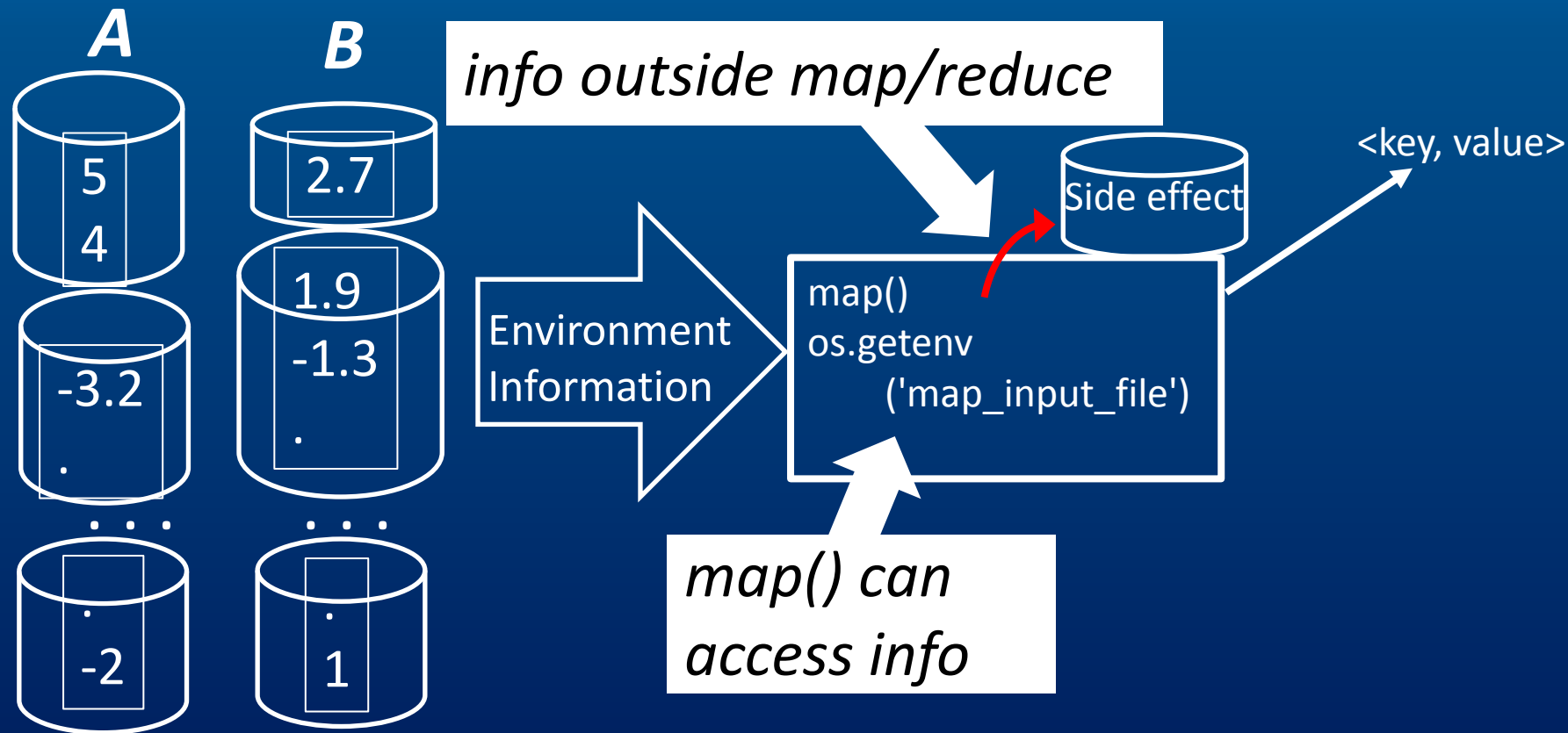
- Problem: array partitions don't have an index



Vector Multiplication



Vector Multiplication



Vector Multiplication

A

1, 5
2, 4

3, -3.2

.

...

N, -2

B

1, 2.7

2, 1.9

3, -1.3

.

...

N, 1

- Let's assume:

← – each line already has
<index, number>

Vector Multiplication

A

1, 5
2, 4

3, -3.2

.

...

.

N, -2

B

1, 2.7

2, 1.9

3, -1.3

.

...

.

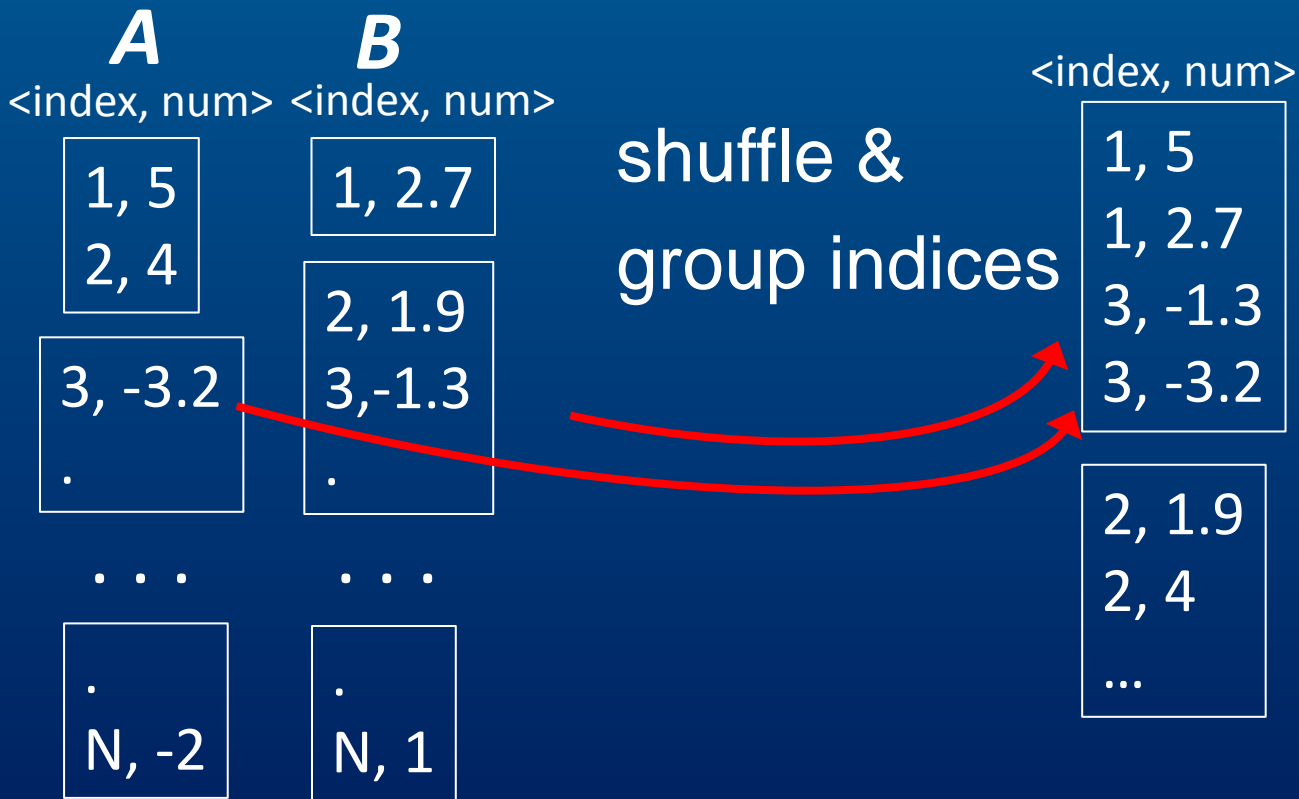
N, 1

- Let's assume:

← – each line already has
<index, number>

*Note: mapper only needs to
pass data (identity function)*

Vector Multiplication



Vector Multiplication

A, B grouped

<index, num>

1, 5

1, 2.7

3, -1.3

3, -3.2

2, 1.9

2, 4

...

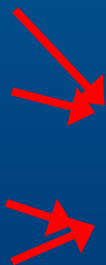
What should
reducers do?

Vector Multiplication

A, B grouped

<index, num>

1, 5
1, 2.7
3, -1.3
3, -3.2



2, 1.9
2, 4



...

Reducer:

-get pairs of

<index, number>

Vector Multiplication

A, B grouped

<index, num>

1, 5
1, 2.7
3, -1.3
3, -3.2

subtotals

+

17.66

2, 1.9
2, 4

7.6

...

Reducer:

-get pairs of

<index, number>

-multiply & add

Vector Multiplication

A, B grouped

<index, num>

1, 5
1, 2.7
3, -1.3
3, -3.2

subtotals

+

17.66

2, 1.9
2, 4

7.6

...

Reducer:

-get pairs of

<index, number>

-multiply & add

(Still need get total sum, but should be largely reduced)

Computational Costs

In Vector Multiplication

Computational Costs

- For Vector Multiplication
 - *How many <index, number> are output from map()?*

Computational Costs

- For Vector Multiplication
 - *How many <index, number> are output from map()?*
 - *How many <index> groups have to be shuffled?*

Computational Costs

- How many <index, number> are output ?

A

1, 5
2, 4
3, -3.2
.
.
.
N, -2

B

1, 2.7
2, 1.9
3, -1.3
.
.
.
N, 1

For: 2 Vectors with
 N indices each

Then:

$2N$ <index, number>
are output from map()

Computational Costs

- How many `<index>` groups have to be shuffled?

A, B grouped

`<index, num>`

1, 5
1, 2.7
3, -1.3
3, -3.2

2, 1.9
2, 4
...

For: $2N$ indices and
 N pairs

Then:

N groups are shuffled to
reducers

Computational Costs

- Can we reduce shuffling?

Computational Costs

- Can we reduce shuffling?
- Try: 'combine' map indices in mapper
(works better for Wordcount)

Computational Costs

- Can we reduce shuffling?
- Or Try: use index ranges of length R

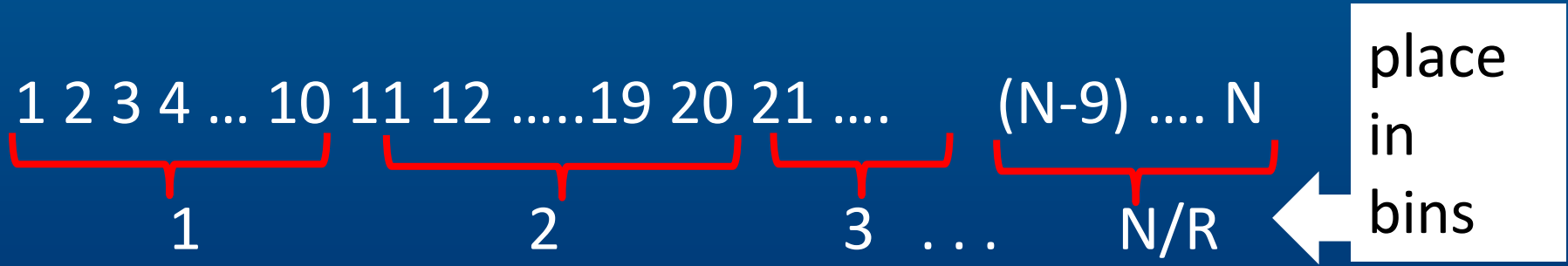
Computational Costs

- Index Ranges: let $R=10$ & bin the array indices

1 2 3 4 ... 10 11 1219 20 21 (N-9) ... N ← N keys

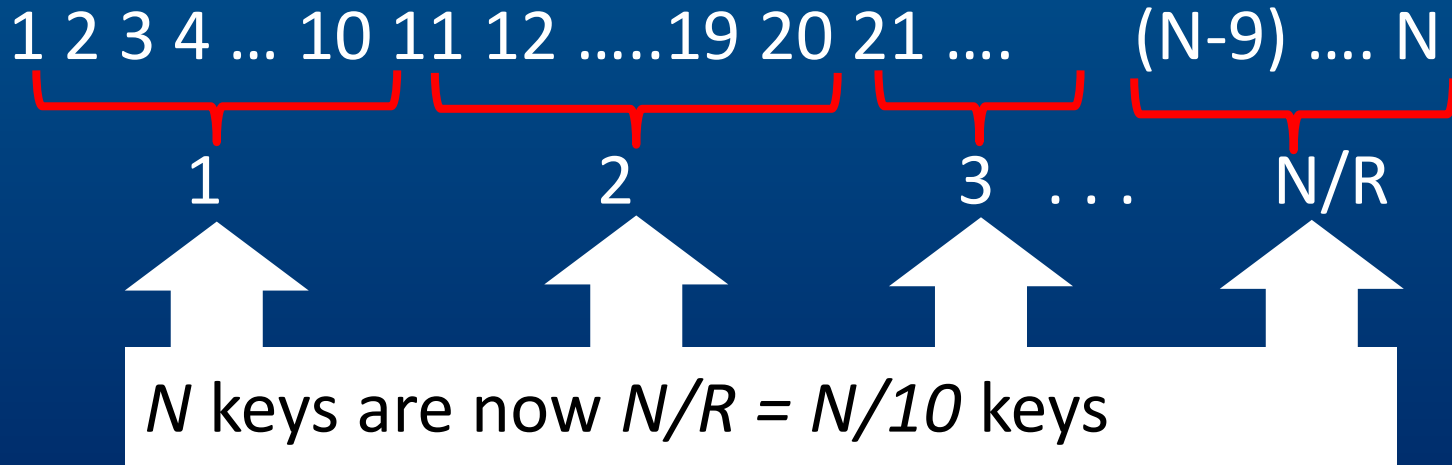
Computational Costs

- Index Ranges: let $R=10$ & bin the array indices



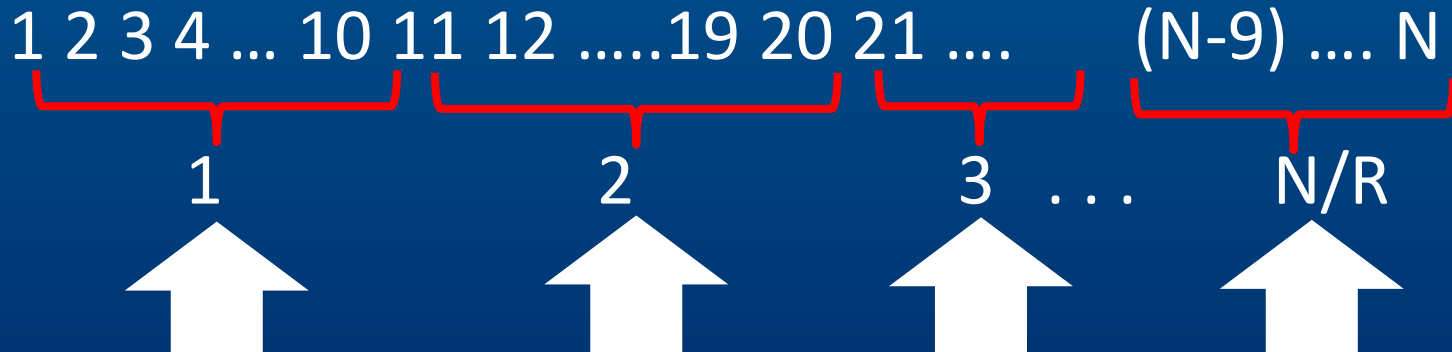
Computational Costs

- For example, let $R=10$, and bin the array indices



Computational Costs

- For example, let $R=10$, and bin the array indices



N keys are now $N/R=N/10$ keys

$\langle \text{key}, \text{value} \rangle$ is now

$\langle \text{index bin}, \text{original-index number} \rangle$

Computational Costs

- Now shuffling costs depend on N/R groups

If: $R=1$

Then: $N/R=N$ groups (same as before)

If: $R>1$

Then: $N/R < N$ (less shuffling to do)

Computational Costs

- Trade-offs:

If:

size of (N/R) \uparrow

Then:

shuffle costs \uparrow

Computational Costs

- Trade-offs:

If:

size of (N/R) \uparrow

Then:

shuffle costs \uparrow

But:

reducer complexity \downarrow

Computational Costs

- Trade-offs:

If:

size of (N/R) \uparrow

Then:

shuffle costs \uparrow

But:

reducer complexity \downarrow

-you control R
(specific tradeoffs
depend on data
and hardware)

Vector to Matrices

- Matrix multiplication needs row-index and col-index in the keys
- Matrix multiplication more pertinent to data analytic topics

Summary

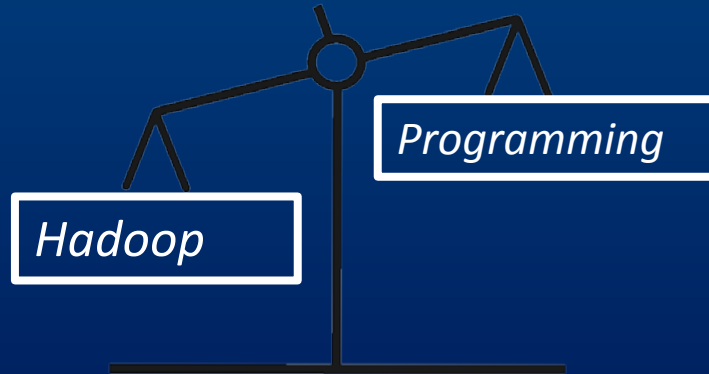
And Looking Beyond

Task Decomposition

- mappers are separate and independent
- mappers work on data parts

Summary of Map/Reduce Design Considerations

- `<key, value>` must enable correct output
- Let Hadoop do the hard work
- Trade-offs



Summary of Map/Reduce Design Considerations

- Common mappers:
 - Filter (subset data)
 - Identity (just pass data)
 - Splitter (as for counting)

Summary of Map/Reduce Design Considerations

- Composite <keys>

Summary of Map/Reduce Design Considerations

- Composite <keys>
- Extra info in <values>

Summary of Map/Reduce Design Considerations

- Composite <keys>
- Extra info in <values>
- Cascade Map/Reduce jobs

Summary of Map/Reduce Design Considerations

- Composite <keys>
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- Bin keys into ranges

Summary of Map/Reduce Design Considerations

- Composite <keys>
- Extra info in <values>
- Cascade Map/Reduce jobs
- Bin keys into ranges
- Aggregate map output when possible
(combiner option)

Potential Limitations Map/Reduce

- Must fit `<key, value>` paradigm
- Map/Reduce data not persistent
- Requires programming/debugging
- Not interactive

Beyond Map/Reduce

- Data access tools (Pig, HIVE)
 - SQL like syntax
- Interactivity & Persistency (Spark)