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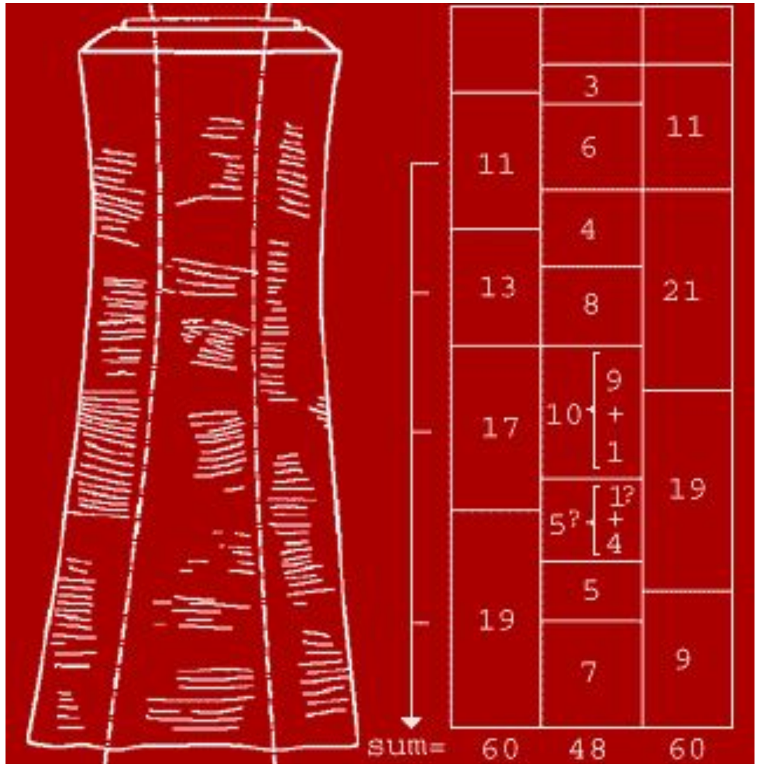
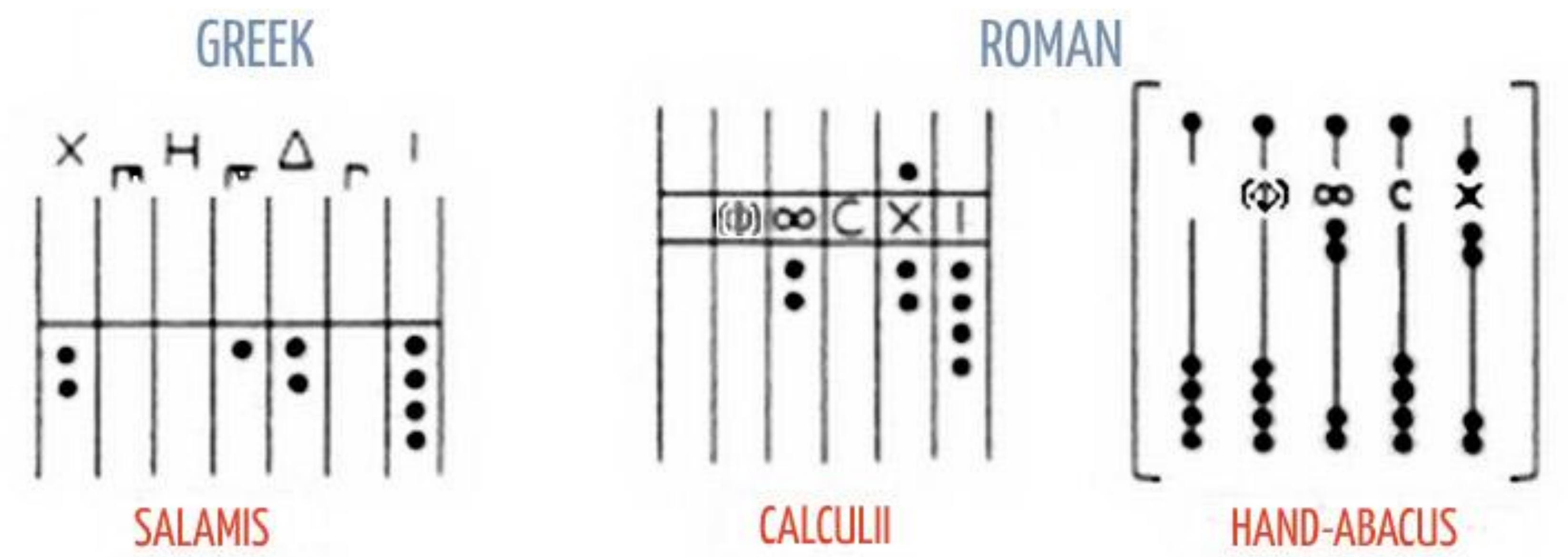
# Counting

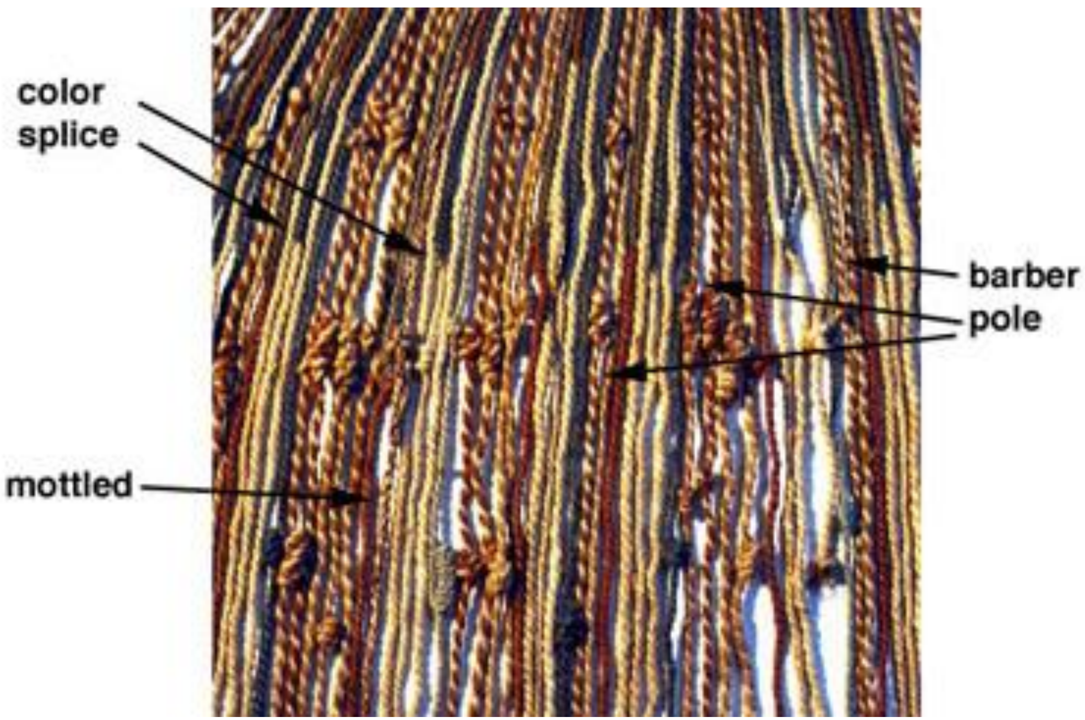
# Ishango Bone (20,000 Years Old!)

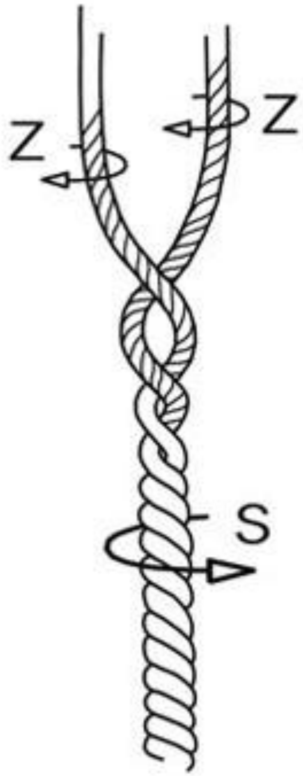


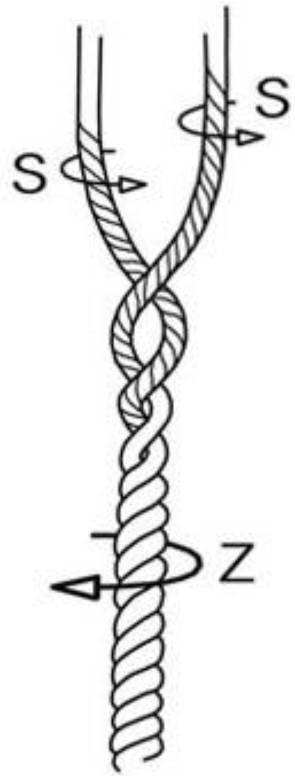
# Ancient Counting Devices (500 BCE - 500 CE)



# Khipu (1400)



Soroban (1930)

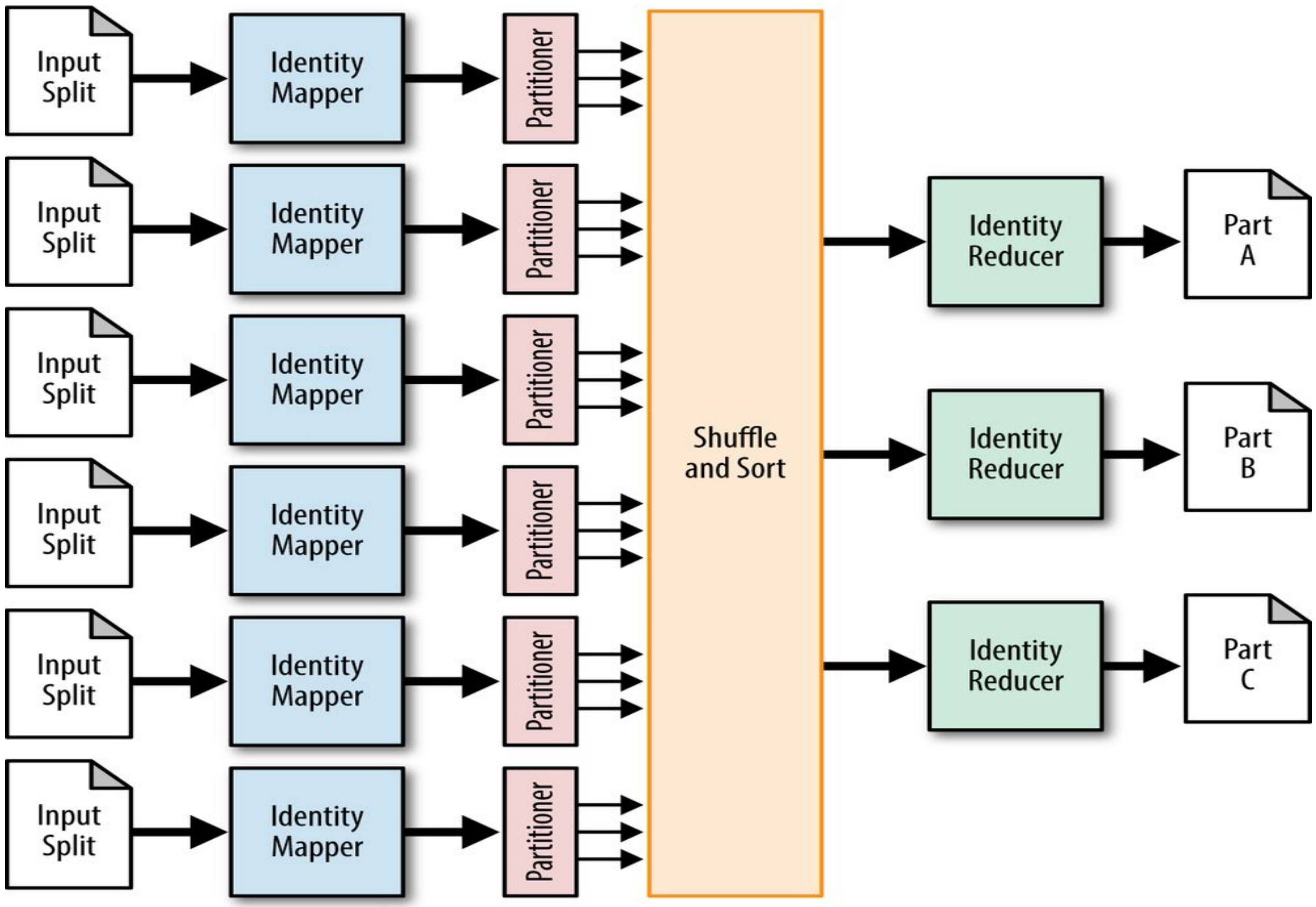

SEIKO
UC-2100

# Number of unique users interested in “**blue shoes**”

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Event_ID** | **User_ID** | **Segment** | **Event_Type** | | | | | | |
| 2 | 1 | 26 | red shoes | clicked | | **Segment** | **Event Type** | **Total** | **Uniques** | |
| 3 | 2 | 3 | blue shoes | clicked | | blue shoes | clicked | 20 | 5 | |
| 4 | 3 | 40 | green shoes | viewed | | blue shoes | viewed | 35 | 10 | |
| 5 | 4 | 38 | green shoes | clicked | | green shoes | clicked | 20 | 5 | |
| 6 | 5 | 4 | red shirts | viewed | | green shoes | viewed | 35 | 10 | |
| 7 | 6 | 5 | white bags | clicked | | red shoes | clicked | 20 | 5 | |
| 8 | 7 | 2 | red shirts | clicked | | red shoes | viewed | 35 | 10 | |
| 9 | 8 | 21 | red shoes | clicked | | white bags | clicked | 20 | 5 | |
| 10 | 9 | 23 | blue shoes | viewed | | white bags | viewed | 35 | 10 | |
| 11 | 10 | 26 | red shoes | clicked | | yellow shirts | clicked | 20 | 5 | |
| 12 | 11 | 13 | yellow shirts | clicked | | yellow shirts | viewed | 35 | 10 | |
| 13 | 12 | 24 | green shoes | viewed | | red shirts | clicked | 20 | 5 | |
| 14 | 13 | 3 | green shoes | viewed | | red shirts | viewed | 35 | 10 | |
| 15 | 14 | 16 | red shoes | clicked | | | | | | |
| 16 | 15 | 5 | red shirts | viewed | | | | | | |

# Distributed Systems

# Map/Reduce



Input Split
Input Split
Input Split
Input Split
Input Split
Input Split
Identity Mapper
Identity Mapper
Identity Mapper
Identity Mapper
Identity Mapper
Identity Mapper
Partitioner
Partitioner
Partitioner
Partitioner
Partitioner
Partitioner
Shuffle and Sort
Identity Reducer
Identity Reducer
Identity Reducer
Part A
Part B
Part C

# Count-distinct Problem

Count-distinct problem in large datasets.

## Count-distinct problem

Finding the number of distinct elements in a dataset with repeated elements.

Count-distinct Problem

or

Cardinality Estimation Problem

Probabilistic Data Structures

Vs

Deterministic Data Structures

# Deterministic Data Structures

The result of following functions:

- Insert
- Find
- Delete
- Count
- ...

Are always consistent.

Example: Set, Arrays,...

# Probabilistic Data Structures

The result of following functions:

- Insert
- Find
- Delete
- Count
- ...

Are not always consistent.

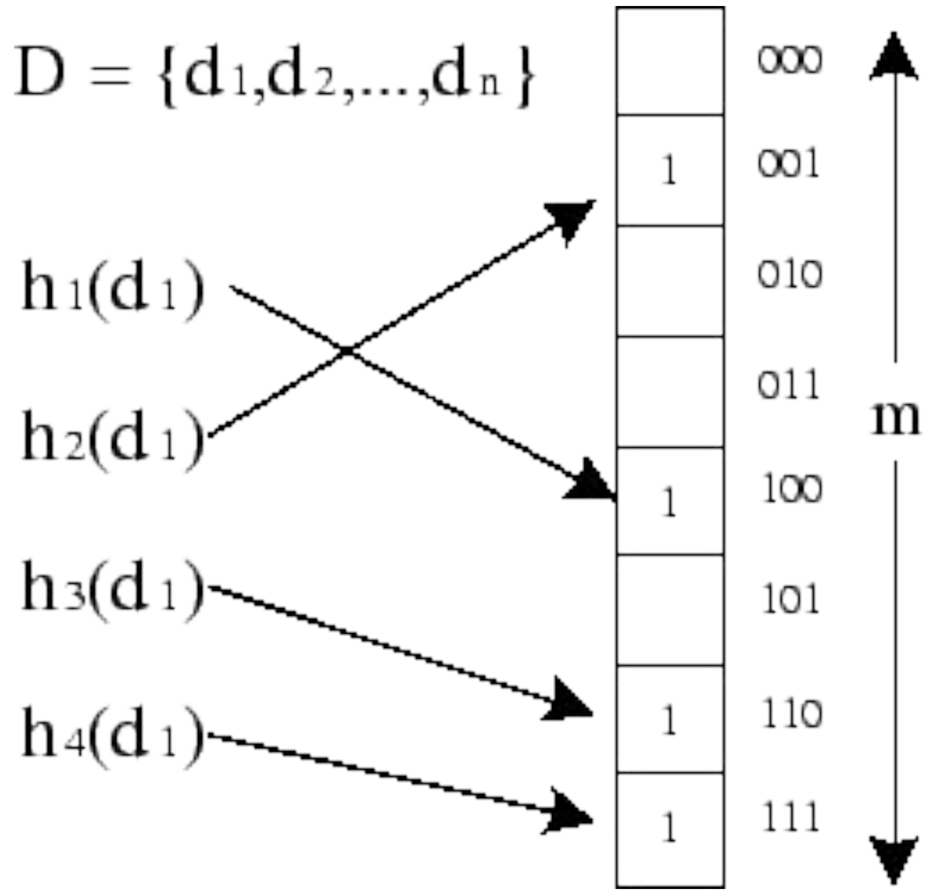
Examples: BloomFilter, HyperLogLog, Count-min Sketch, MinHash,...

# Number of unique users interested in “**blue shoes**”

| Event_ID | User_ID | Segment | Event_Type |
|---|---|---|---|
| 1 | 26 | red shoes | clicked |
| 2 | 3 | blue shoes | clicked |
| 3 | 40 | green shoes | viewed |
| 4 | 38 | green shoes | clicked |
| 5 | 4 | red shirts | viewed |
| 6 | 5 | white bags | clicked |
| 7 | 2 | red shirts | clicked |
| 8 | 21 | red shoes | clicked |
| 9 | 23 | blue shoes | viewed |
| 10 | 26 | red shoes | clicked |
| 11 | 13 | yellow shirts | clicked |
| 12 | 24 | green shoes | viewed |
| 13 | 3 | green shoes | viewed |
| 14 | 16 | red shoes | clicked |
| 15 | 5 | red shirts | viewed |

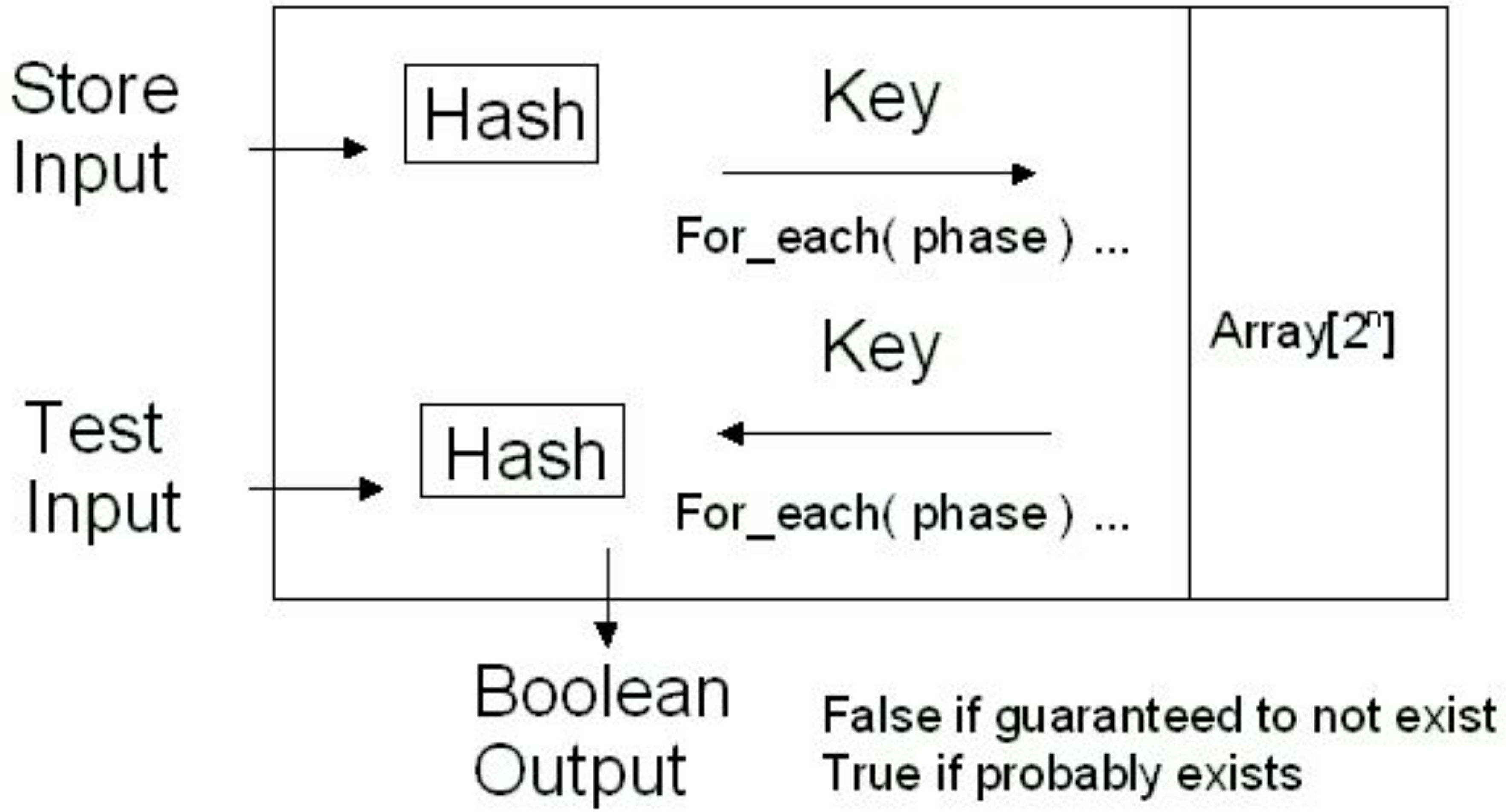
| Segment | Event Type | Total | Uniques |
|---|---|---|---|
| blue shoes | clicked | 20 | 5 |
| blue shoes | viewed | 35 | 10 |
| green shoes | clicked | 20 | 5 |
| green shoes | viewed | 35 | 10 |
| red shoes | clicked | 20 | 5 |
| red shoes | viewed | 35 | 10 |
| white bags | clicked | 20 | 5 |
| white bags | viewed | 35 | 10 |
| yellow shirts | clicked | 20 | 5 |
| yellow shirts | viewed | 35 | 10 |
| red shirts | clicked | 20 | 5 |
| red shirts | viewed | 35 | 10 |

# BloomFilter




A Bloom Filter that uses 4 hash functions and has a size of m=8 bits.

# Bloom Filter Process



# BloomFilter

- Compact with controllable error rate
- Great for fast filtering (is value V in set S?)
  - Fraud Detection
  - DDOS Attack Prevention
  - …
- Great for problems not sensitive to false positive results
- Not that great for distinct count of large datasets
- It will be sparse for small datasets
- Dynamic Block-Partitioned BloomFilters

# HyperLogLog

Q: How many distinct elements are in an infinite stream of data?

Similar to

Q: How many times the coin is flipped in coin flipping?

# Coin Flipping

- Long runs of **heads** in random series are rare
- The longer you look, the more likely you will find one
- Long runs are very rare and are correlated with how many coins you've flipped

# Basic HyperLogLog Algorithm

```
n = 0
For each input item:
    Hash item into bit string
    Count trailing zeros in bit string
    if this count > n:
        Let n = count
Estimated Cardinality ("Count Distinct") = 2^n
```

# HyperLogLog

- Great for distinct count of large datasets
  - Fixed Memory
- Some set operations:
  - Union
- Higher error ratio
- Limited spectrum for set Intersection operation
- The HyperLogLog algorithm is able to estimate cardinalities of 10^9 with a typical error rate of 2%, using 1.5 kB of memory.

# Approximate Count in Apache Spark

`countApproxDistinct`(*relativeSD=0.05*)

**Note:** Experimental

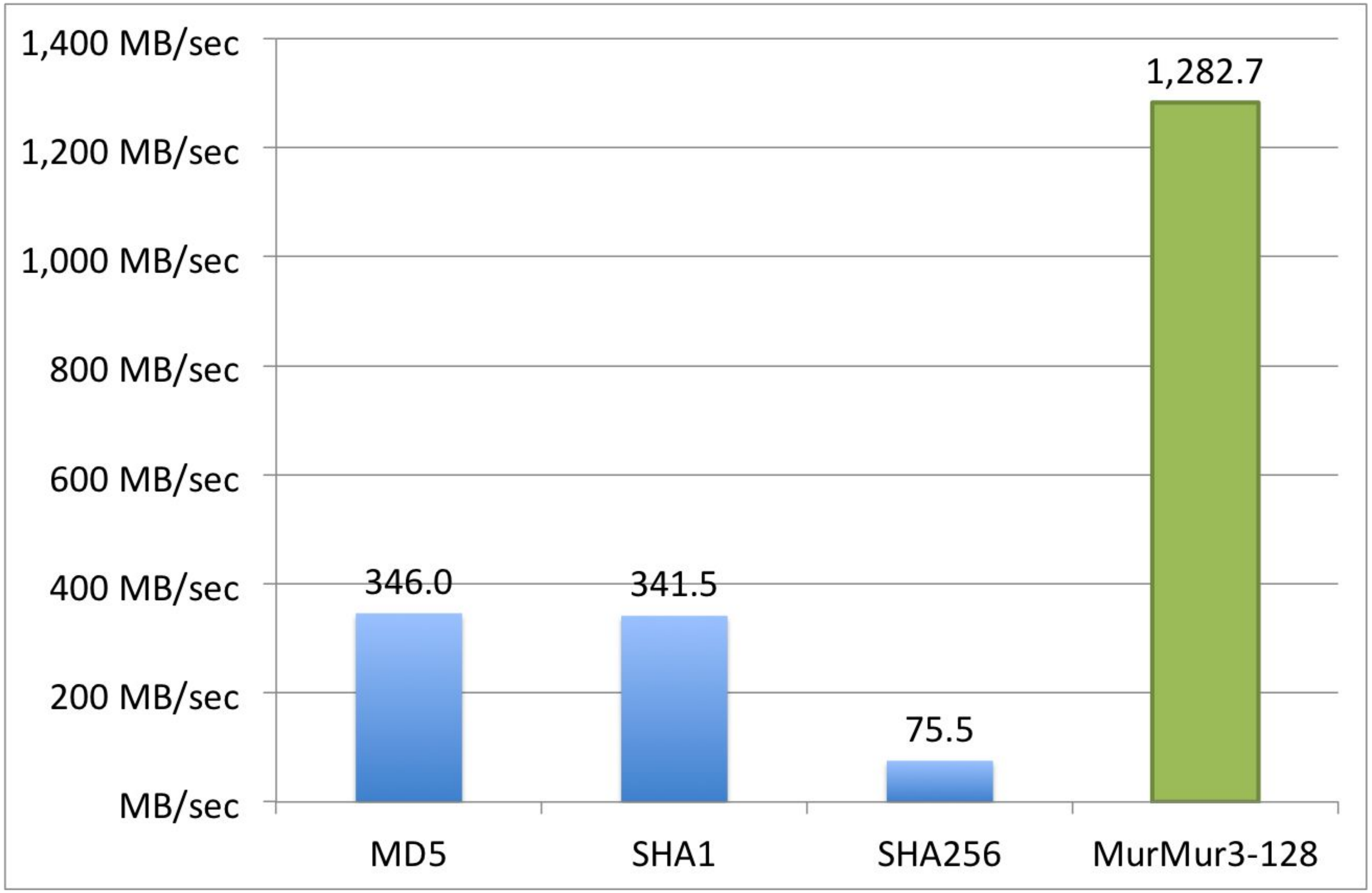
Return approximate number of distinct elements in the RDD.

The algorithm used is based on streamlib's implementation of "HyperLogLog in Practice: Algorithmic Engineering of a State of The Art Cardinality Estimation Algorithm", available here.

**Parameters:** **relativeSD** – Relative accuracy. Smaller values create counters that require more space. It must be greater than 0.000017.

```
>>> n = sc.parallelize(range(1000)).map(str).countApproxDistinct()
>>> 900 < n < 1100
True
>>> n = sc.parallelize([i % 20 for i in range(1000)]).countApproxDistinct()
>>> 16 < n < 24
True
```

# Hash Functions



# References


- https://highlyscalable.wordpress.com/2012/05/01/probabilistic-structures-web-analytics-data-mining/
- https://en.wikipedia.org/wiki/Count-distinct_problem
- https://en.wikipedia.org/wiki/Category:Probabilistic_data_structures
- http://www.slideshare.net/a235/probabilistic-data-structures-and-approximate-solutions
- http://dl.acm.org/citation.cfm?doid=2452376.2452456
- http://www.ee.ryerson.ca/~elf/abacus/images/fig-antiquity.JPG
- https://pdfs.semanticscholar.org/5da8/bf81712187712aed159aed62e38fb012872e.pdf

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Thank You!