Mehrdad Pazooki

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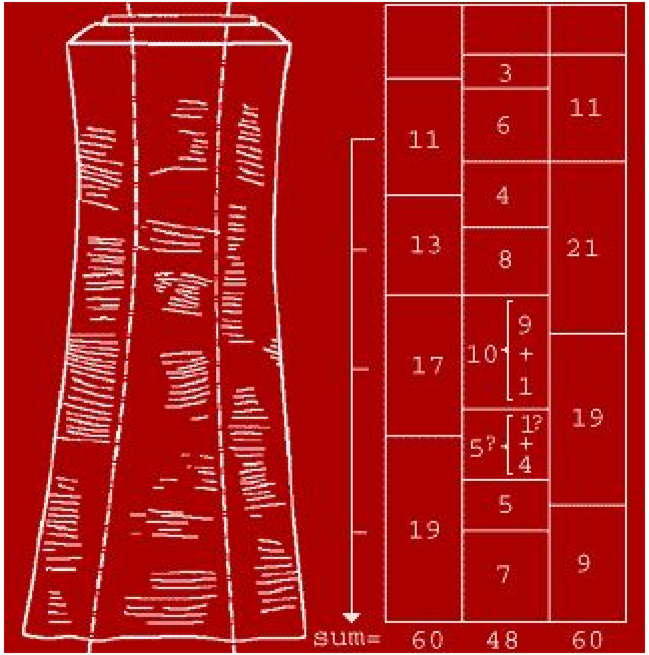
Slides: https://github.com/pazooki/presentations

Count-distinct Problem

Count-distinct problem in large datasets.

Ishango Bone (20,000 Years Old!)



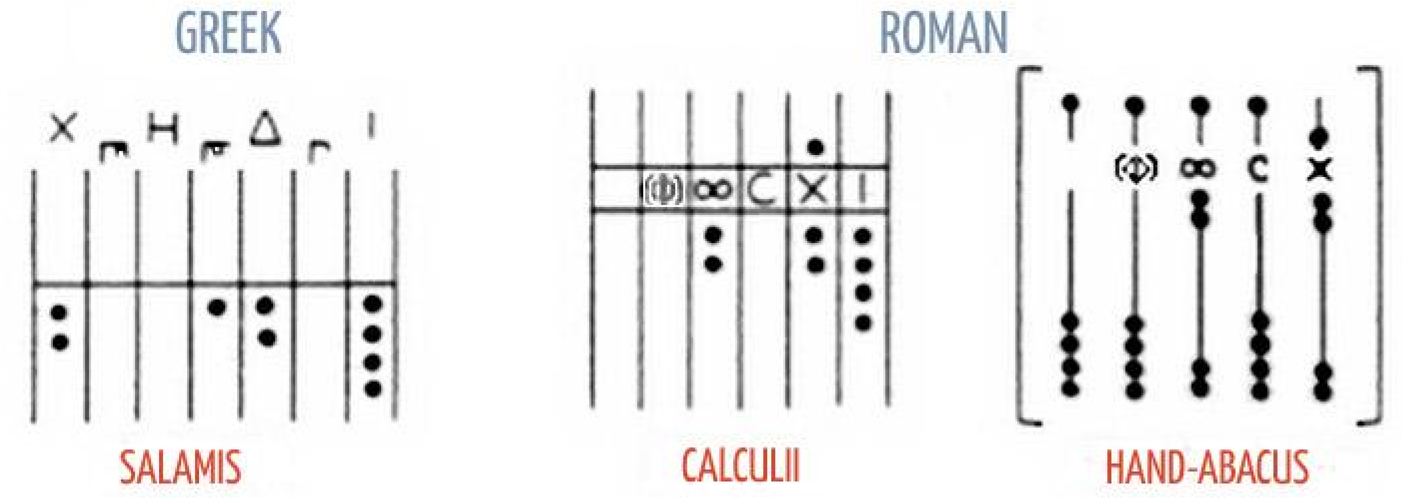
11
13
17
19

3
6
4
8
10 [9 + 1]
5? [1? + 4]
5
7

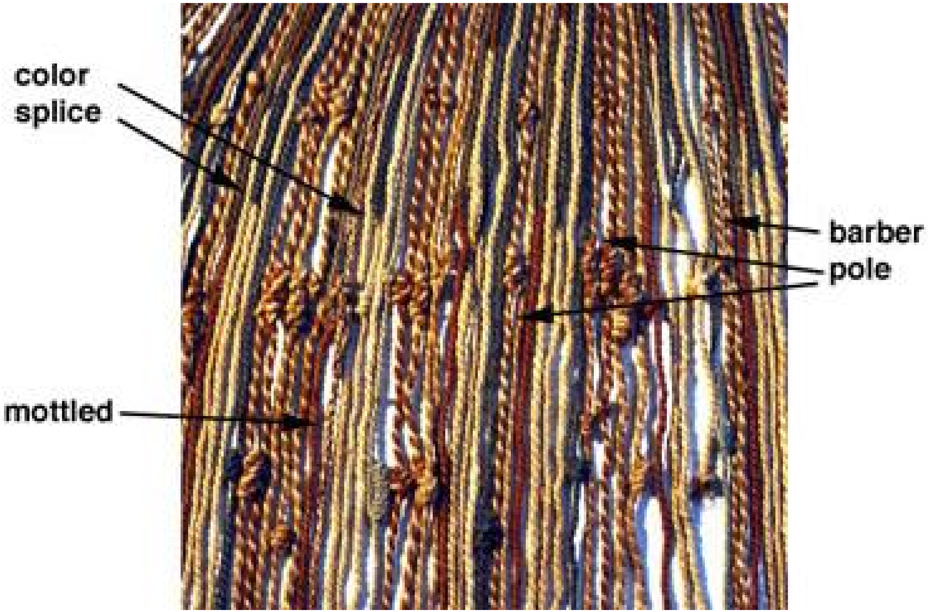
11
21
19
9

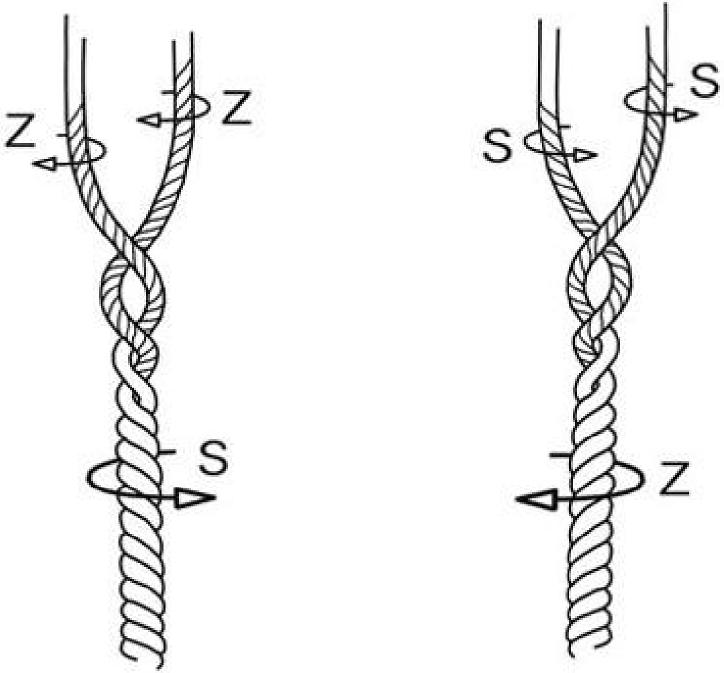
sum= 60 48 60

Ancient Counting Devices (500 BCE - 500 CE)



Khipu (1400)





Soroban (1930)

SEIKO
SEIKO
UC-2100
SPACE
RETURN
OFF
ON

Count-distinct problem

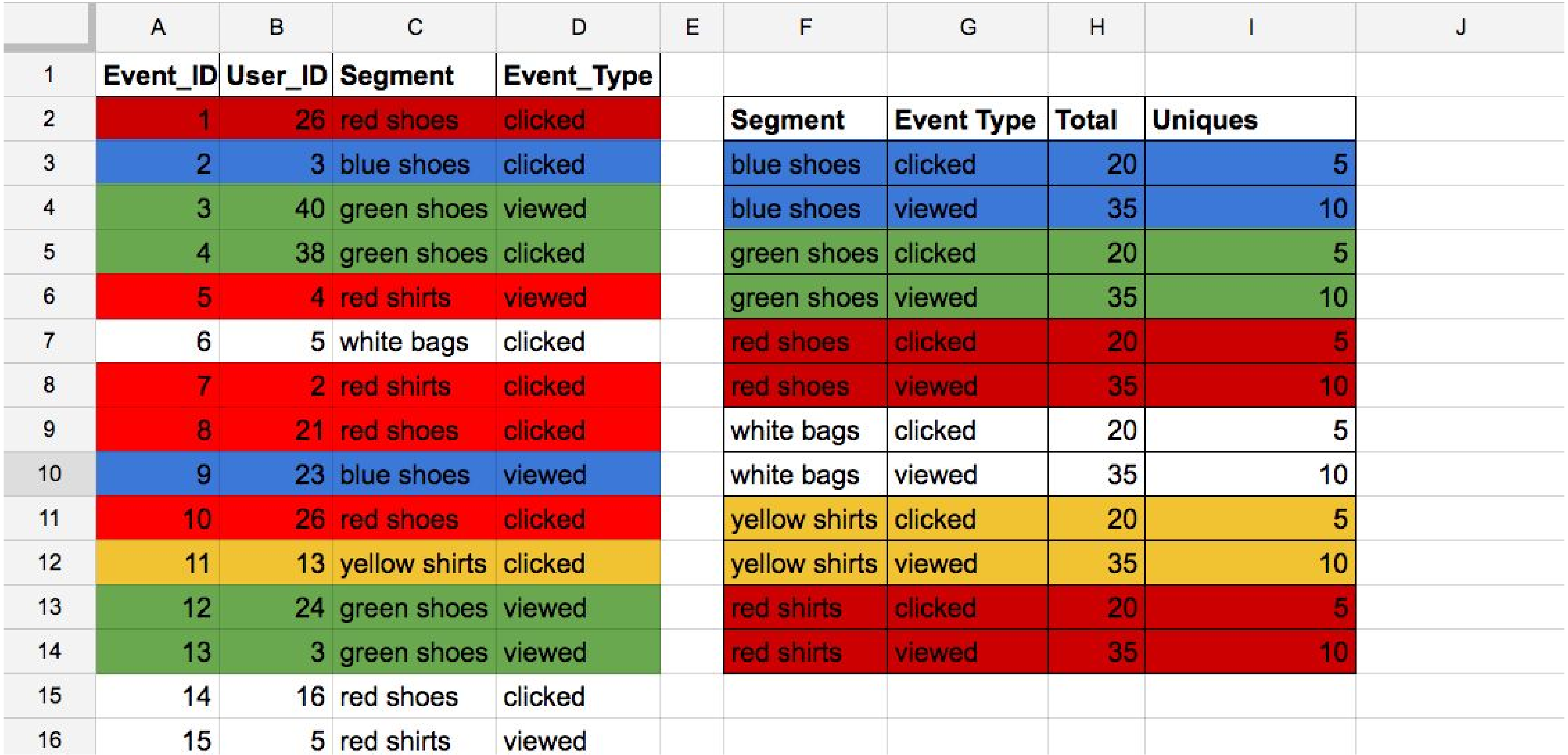
Finding the number of distinct elements in a dataset with repeated elements.

Count-distinct Problem

or

Cardinality Estimation Problem

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

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

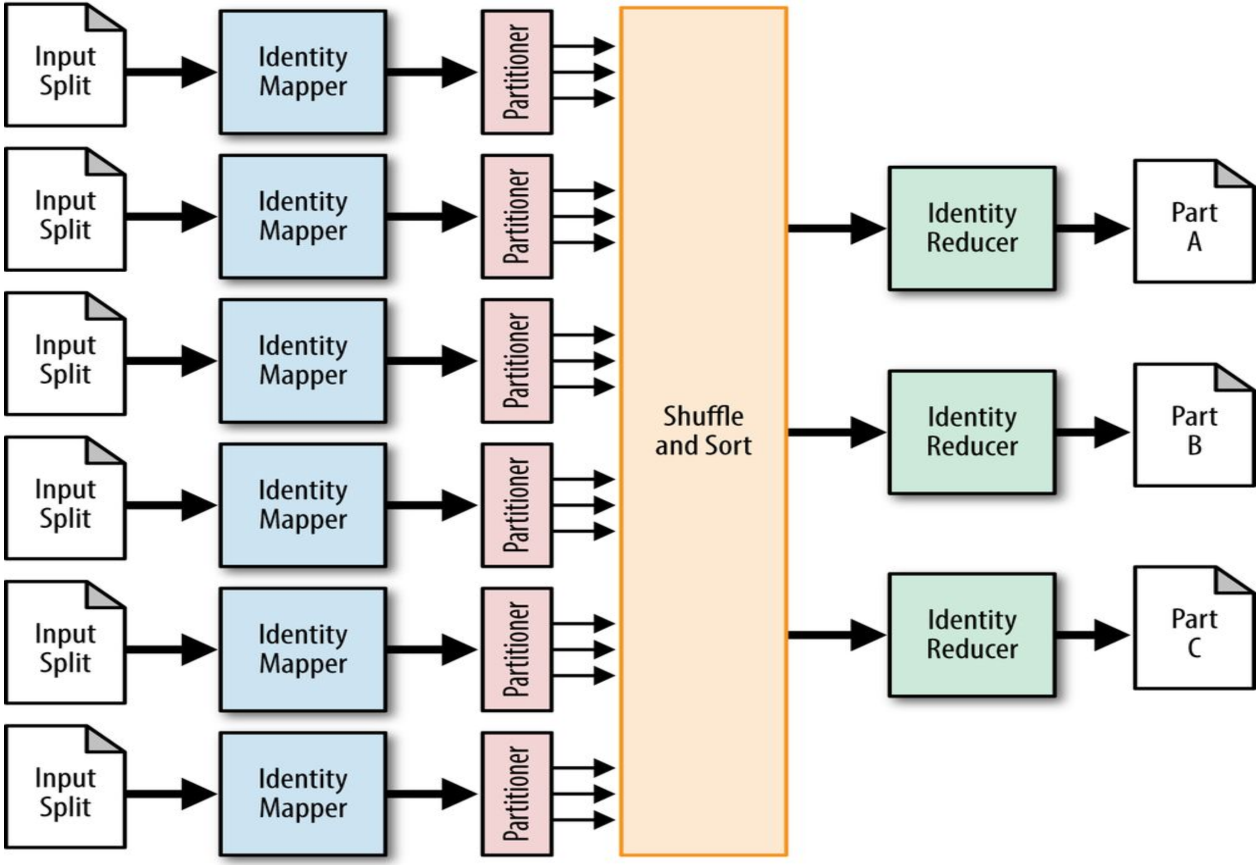
The result of following functions:

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

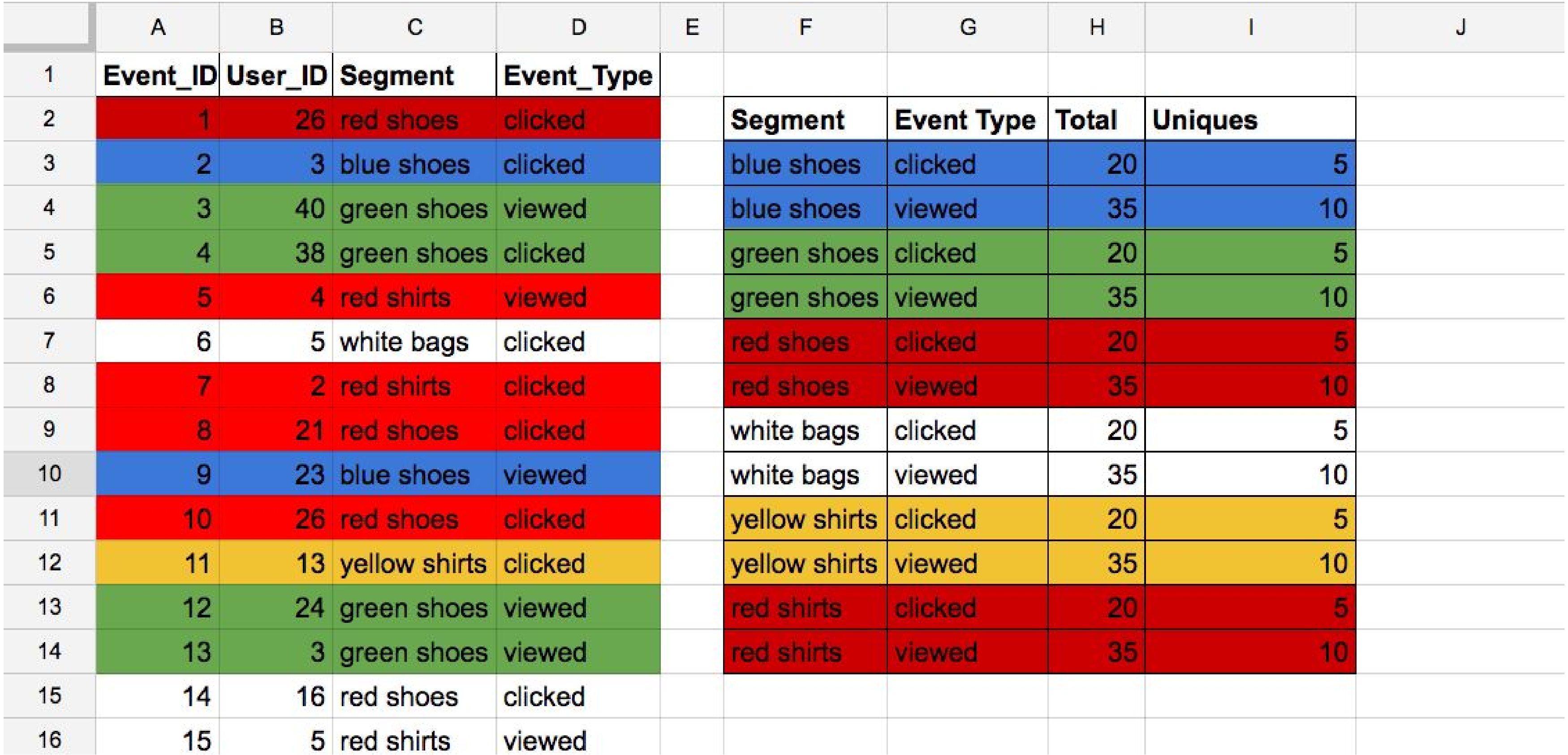
Are not always consistent.

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

Map/Reduce

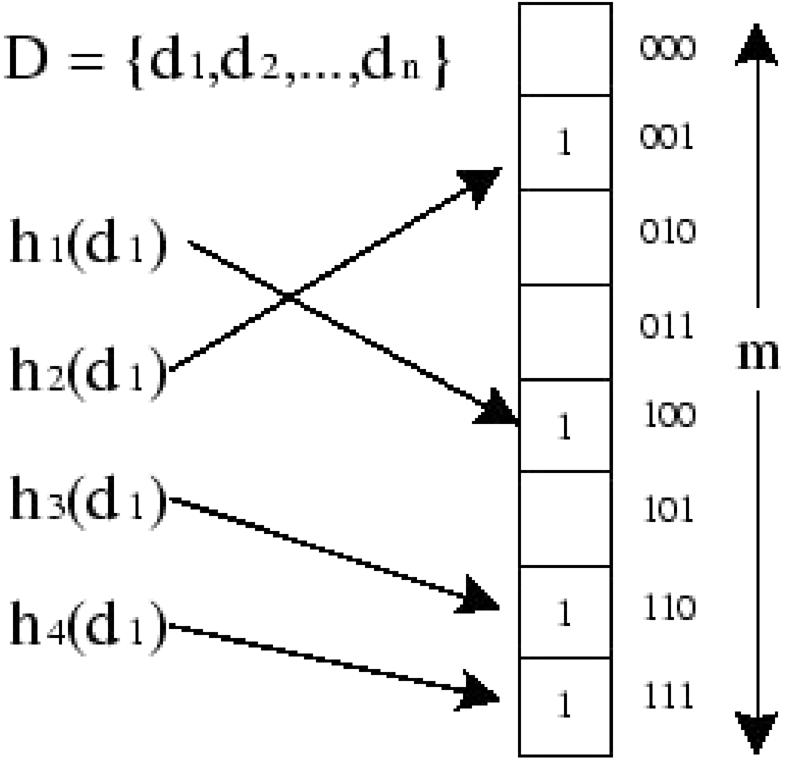

Input Split
Identity Mapper
Partitioner
Input Split
Identity Mapper
Partitioner
Input Split
Identity Mapper
Partitioner
Input Split
Identity Mapper
Partitioner
Input Split
Identity Mapper
Partitioner
Input Split
Identity Mapper
Partitioner
Shuffle and Sort
Identity Reducer
Part A
Identity Reducer
Part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

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



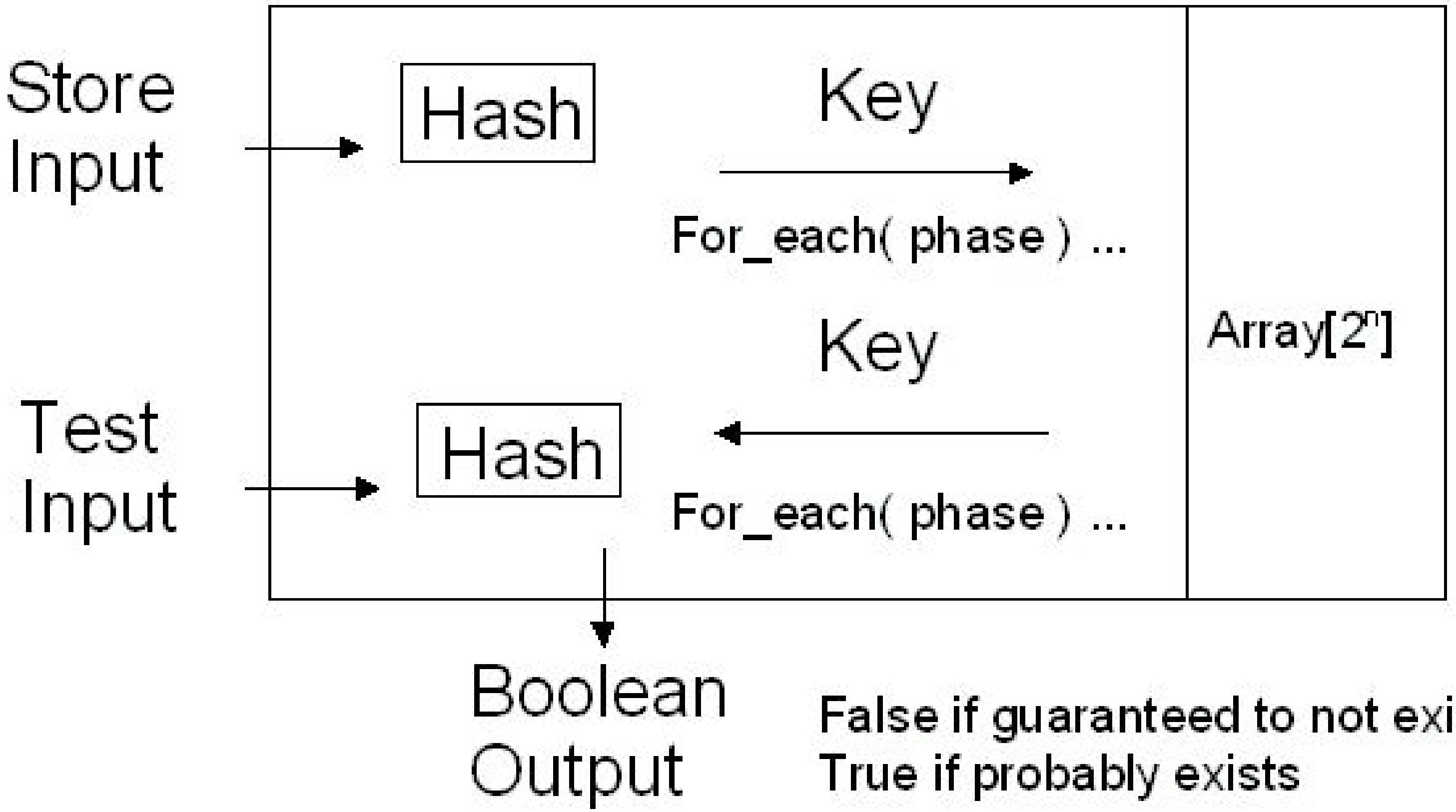
	A	B	C	D	E	F	G	H	I	J
1	Event_ID	User_ID	Segment	Event_Type						
2	1	26	red shoes	clicked		Segment	Event Type	Total	Uniques	
3	2	3	blue shoes	clicked		blue shoes	clicked	20	5	
4	3	40	green shoes	viewed		blue shoes	viewed	35	10	
5	4	38	green shoes	clicked		green shoes	clicked	20	5	
6	5	4	red shirts	viewed		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						

BloomFilter



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

Bloom Filter Process



False if guaranteed to not exist
True if probably exists

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

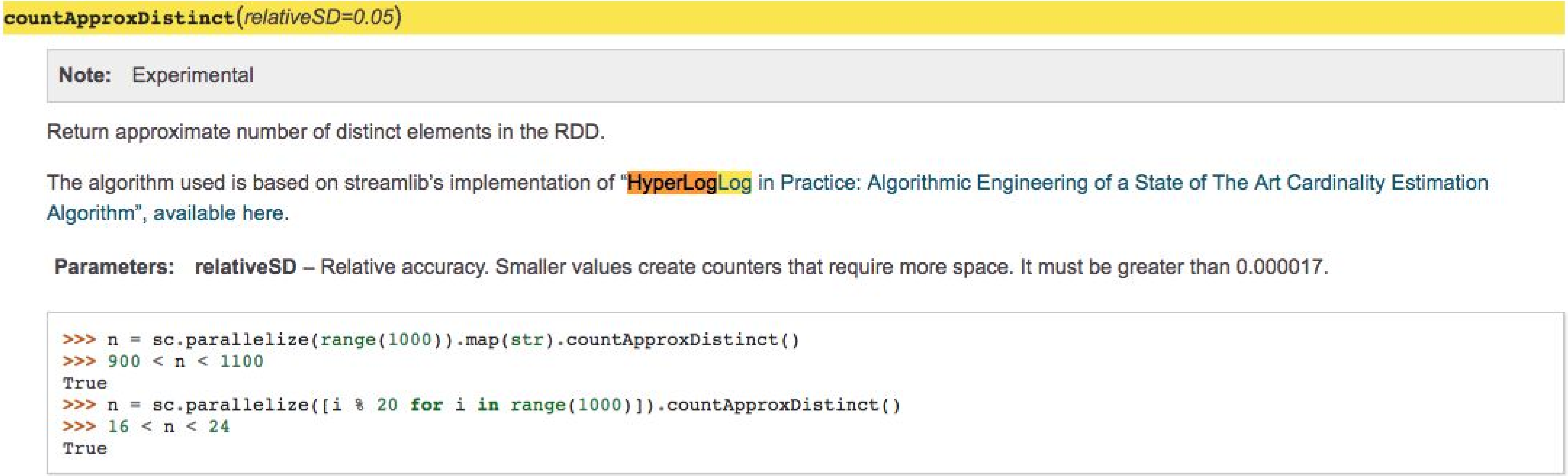
Basic HyperLogLog Algorithm

```
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

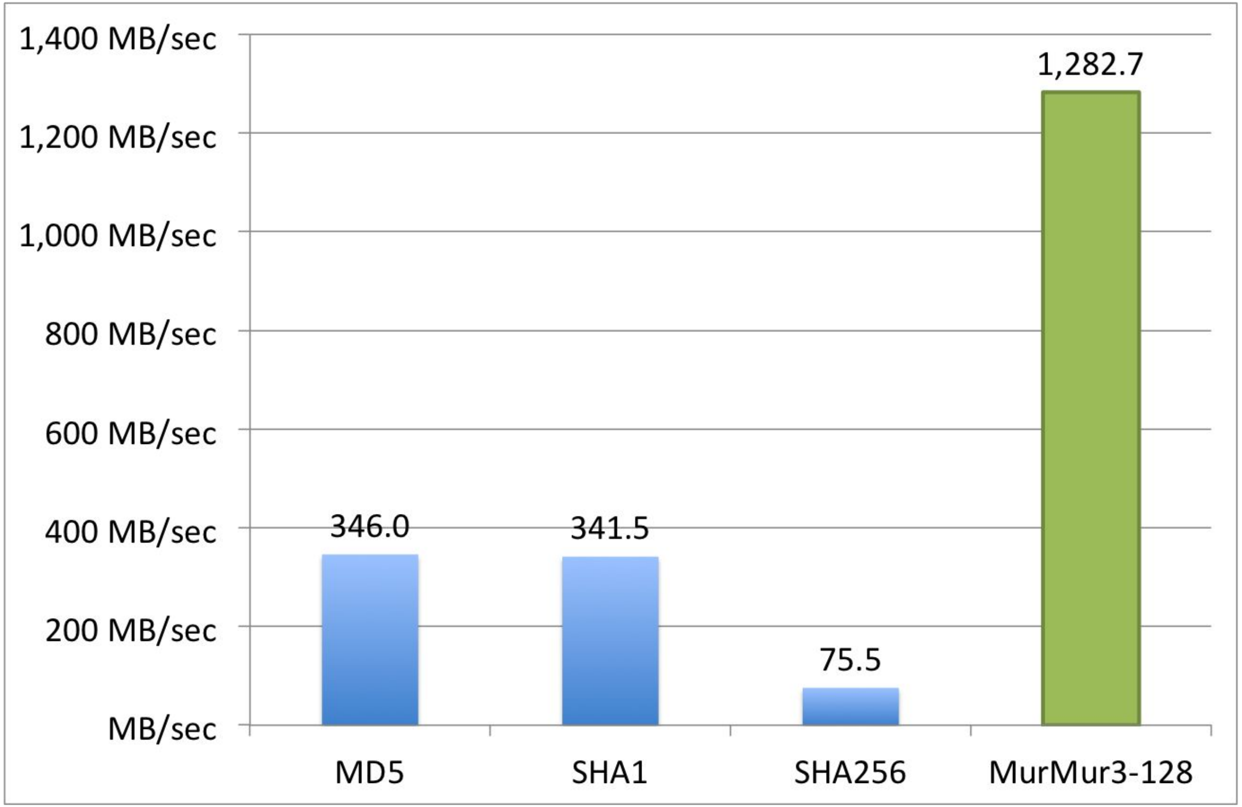
Return approximate number of distinct elements in the RDD.

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

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- 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!

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