Make Your Data

FABulous

Philipp Krenn

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elastic

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Developer 🥑

ViennaDB

Papers We Love Vienna

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What is the perfect datastore solution?

It depends...

Pick your tradeoffs


MAGIC

CAP Theorem

Brewer's Conjecture and the Feasibility of Consistent, Available, Partition-Tolerant Web Services

Seth Gilbert* Nancy Lynch*

Abstract

When designing distributed web services, there are three properties that are commonly desired: consistency, availability, and partition tolerance. It is impossible to achieve all three. In this note, we prove this conjecture in the asynchronous network model, and then discuss solutions to this dilemma in the partially synchronous model.

Consistent

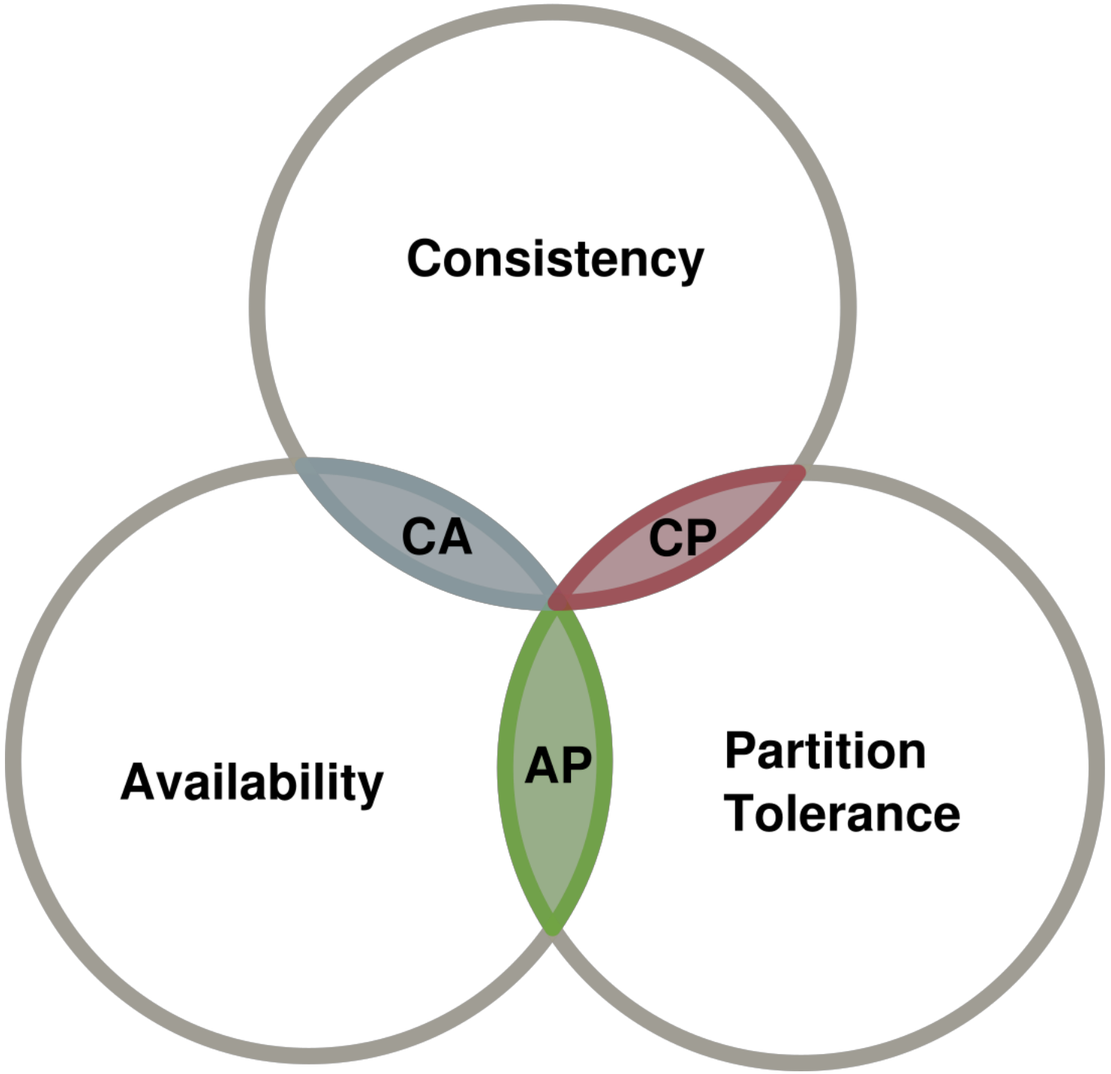
"[...] a **total order** on all operations such that each operation looks as if it were completed at a single instant."

Available

"[...] every request received by a non-failing node in the system must result in a response."

Partition Tolerant

"[...] the network will be allowed to lose arbitrarily many messages sent from one node to another."



https://berb.github.io/diploma-thesis/original/061_challenge.html

Misconceptions

Partition Tolerance is not a choice in a distributed system

Misconceptions

Consistency in ACID is a predicate

Consistency in CAP is a linear order


Robinson Crusoe
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/dev/null breaks CAP: effect of write are always consistent, it's always available, and all replicas are consistent even during partitions.

— https://twitter.com/ashic/status/591511683987701760

FAB Theory

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Mark Harwood

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Fast

Near real-time instead of batch processing

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Accurate

Exact instead of approximate results

Big

Parallelization needed to handle the data

Say Big Data

one more time

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Fast ✅

Big ✅

Accurate ?

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elasticsearch

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Shard

Unit of scale

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"The evil wizard Mondain had attempted to gain control over Sosaria by trapping its essence in a crystal. When the Stranger at the end of Ultima I defeated Mondain and shattered the crystal, the crystal shards each held a refracted copy of Sosaria.

http://www.raphkoster.com/2009/01/08/database-sharding-came-from-uo/

Terms Aggregation

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Word Count	Word Count
Luke **64**	Droid **13**
R2 **31**	3PO **13**
Alderaan **20**	Princess **12**
Kenobi **19**	Ben **11**
Obi-Wan **18**	Vader **11**
Droids **16**	Han **10**
Blast **15**	Jedi **10**
Imperial **15**	Sandpeople **10**

```
PUT starwars
{
  "settings": {
    "number_of_shards": 5,
    "number_of_replicas": 0
  }
}
```

```
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "0" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "1" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "2" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "3" } }
{ "word" : "Luke" }
...
```

Search... (e.g. status:200 AND extension:PHP) Uses lucene query syntax

Add a filter +

starwars

Data Options

Metrics

Tag Size Count

Buckets

Tags

Aggregation

Terms

Field

word.keyword

Order By

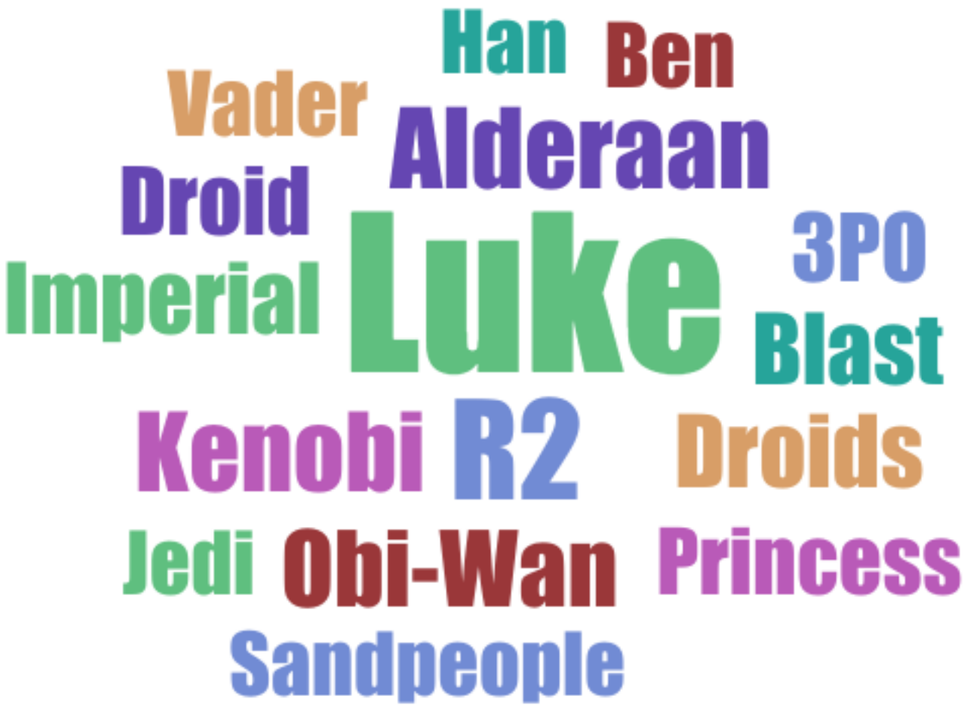
metric: Count

Order **Size**

Descending 25

Group other values in separate bucket

Show missing values



```
GET starwars/_search
{
  "query": {
    "match": {
      "word": "Luke"
    }
  }
}
```

```
{
  "took": 6,
  "timed_out": false,
  "_shards": {
    "total": 5,
    "successful": 5,
    "skipped": 0,
    "failed": 0
  },
  "hits": {
    "total": 64,
    "max_score": 3.2049506,
    "hits": [
      {
        "_index": "starwars",
        "_type": "_doc",
        "_id": "0vVdy2IBkmPuaFRg659y",
        "_score": 3.2049506,
        "_routing": "1",
        "_source": {
          "word": "Luke"
        }
      },
      ...
```

```
GET starwars/_search
{
  "aggs": {
    "most_common": {
      "terms": {
        "field": "word.keyword",
        "size": 1
      }
    }
  },
  "size": 0
}
```

```
{
  "took": 13,
  "timed_out": false,
  "_shards": {
    "total": 5,
    "successful": 5,
    "skipped": 0,
    "failed": 0
  },
  "hits": {
    "total": 288,
    "max_score": 0,
    "hits": []
  },
  "aggregations": {
    "most_common": {
      "doc_count_error_upper_bound": 10,
      "sum_other_doc_count": 232,
      "buckets": [
        {
          "key": "Luke",
          "doc_count": 56
        }
      ]
    }
  }
}
```

```
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "0" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "1" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "2" } }
{ "word" : "Luke" }
...
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "8" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "9" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "0" } }
{ "word" : "Luke" }
{ "index" : { "_index" : "starwars", "_type" : "_doc", "routing": "0" } }
{ "word" : "Luke" }
...
```

Routing

```
shard# = hash(_routing) % #primary_shards
```

```
GET _cat/shards?index=starwars&v

index     shard prirep state   docs store ip           node
starwars 3     p      STARTED    58 6.4kb 172.19.0.2 Q88C3vO
starwars 4     p      STARTED    26 5.2kb 172.19.0.2 Q88C3vO
starwars 2     p      STARTED    71 6.9kb 172.19.0.2 Q88C3vO
starwars 1     p      STARTED    63 6.6kb 172.19.0.2 Q88C3vO
starwars 0     p      STARTED    70 6.7kb 172.19.0.2 Q88C3vO
```

(Sub) Results Per Shard

```
shard_size = (size * 1.5 + 10)
```

How Many?

Results per shard

Results for aggregation

```
"doc_count_error_upper_bound": 10

"sum_other_doc_count": 232
```

```
GET starwars/_search
{
  "aggs": {
    "most_common": {
      "terms": {
        "field": "word.keyword",
        "size": 1,
        "show_term_doc_count_error": true
      }
    }
  },
  "size": 0
}
```

```
"aggregations": {
  "most_common": {
    "doc_count_error_upper_bound": 10,
    "sum_other_doc_count": 232,
    "buckets": [
      {
        "key": "Luke",
        "doc_count": 56,
        "doc_count_error_upper_bound": 9
      }
    ]
  }
}
```

```
GET starwars/_search
{
  "aggs": {
    "most_common": {
      "terms": {
        "field": "word.keyword",
        "size": 1,
        "shard_size": 20,
        "show_term_doc_count_error": true
      }
    }
  },
  "size": 0
}
```

```
"aggregations": {
  "most_common": {
    "doc_count_error_upper_bound": 0,
    "sum_other_doc_count": 224,
    "buckets": [
      {
        "key": "Luke",
        "doc_count": 64,
        "doc_count_error_upper_bound": 0
      }
    ]
  }
}
```

Cardinality Aggregation

elastic

Naive implementation: Hash set

Predictable storage and performance?

HyperLogLog in Practice: Algorithmic Engineering of a State of The Art Cardinality Estimation Algorithm

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ABSTRACT

Cardinality estimation has a wide range of applications and is of particular importance in database systems. Various algorithms have been proposed in the past, and the HyperLogLog algorithm is one of them. In this paper, we present a series of improvements to this algorithm that reduce its memory requirements and significantly increase its accuracy for an important range of cardinalities. We have implemented our proposed algorithm for a system at Google and evaluated it empirically, comparing it to the original HyperLogLog algorithm. Like HyperLogLog, our improved algorithm parallelizes perfectly and computes the cardinality estimate in a single pass.

timate significantly for a range of important cardinalities. We evaluate all improvements empirically and compare with the HyperLogLog algorithm from [7]. Our changes to the algorithm are generally applicable and not specific to our system. Like HyperLogLog, our proposed improved algorithm parallelizes perfectly and computes the cardinality estimate in a single pass.

Outline. The remainder of this paper is organized as follows; we first justify our algorithm choice and summarize related work in Section 2. In Section 3 we give background information on our practical use cases at Google and list

[...] the maximum number of leading zeros that occur for all hash values, where intuitively hash values with more leading zeros are less likely and indicate a larger cardinality.

If the bit pattern $0^{n-1}1$ is observed at the beginning of a hash value, then a good estimation of the size of the multiset is 2^n [...].

To reduce the large variability that such a single measurement has, a technique known as stochastic averaging is used.

```
GET starwars/_search
{
  "aggs": {
    "type_count": {
      "cardinality": {
        "field": "word.keyword",
        "precision_threshold": 10
      }
    }
  },
  "size": 0
}
```

```
{
  "took": 3,
  "timed_out": false,
  "_shards": {
    "total": 5,
    "successful": 5,
    "skipped": 0,
    "failed": 0
  },
  "hits": {
    "total": 288,
    "max_score": 0,
    "hits": []
  },
  "aggregations": {
    "type_count": {
      "value": 17
    }
  }
}
```

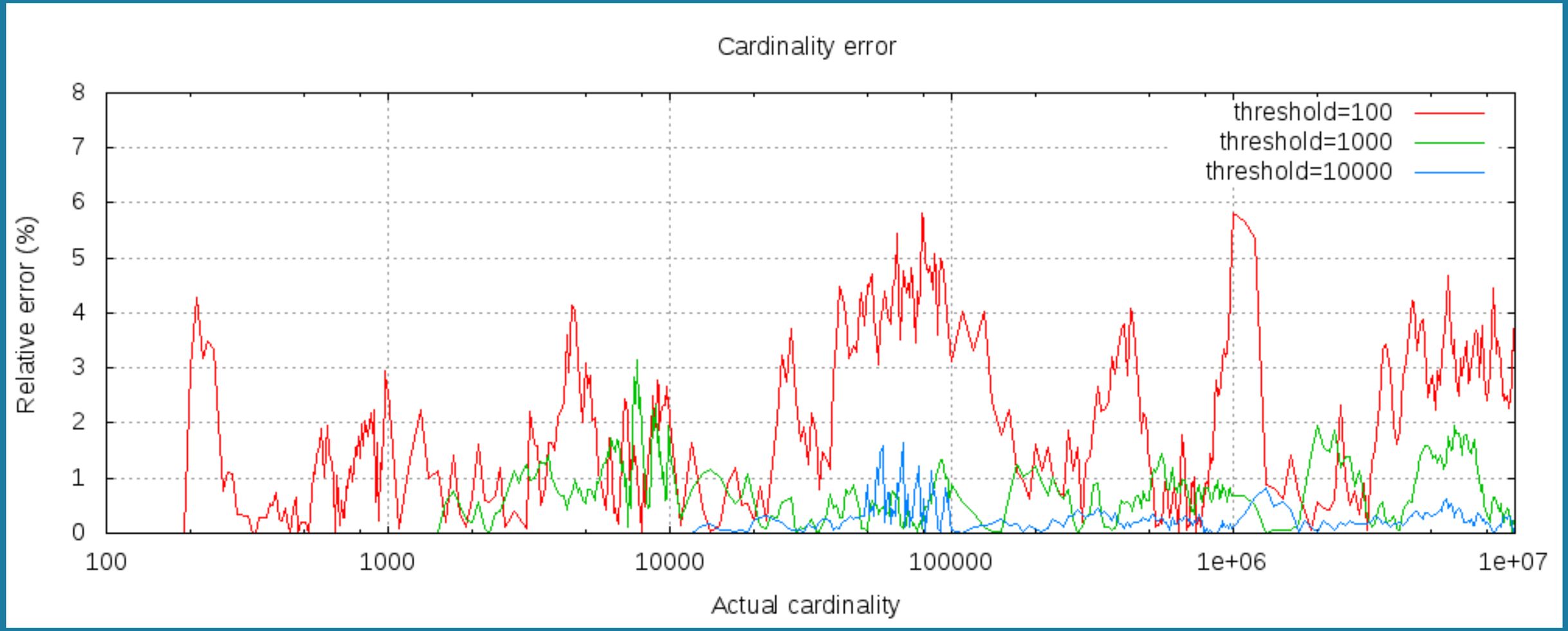
precision_threshold

Default 3,000

Maximum 40,000

Memory

precision_threshold x 8 bytes


Cardinality error
Relative error (%)
0
1
2
3
4
5
6
7
8
100
1000
10000
100000
1e+06
1e+07
Actual cardinality
threshold=100
threshold=1000
threshold=10000

elastic

```
GET starwars/_search
{
  "aggs": {
    "type_count": {
      "cardinality": {
        "field": "word.keyword",
        "precision_threshold": 12
      }
    }
  },
  "size": 0
}
```

```
{
  "took": 12,
  "timed_out": false,
  "_shards": {
    "total": 5,
    "successful": 5,
    "skipped": 0,
    "failed": 0
  },
  "hits": {
    "total": 288,
    "max_score": 0,
    "hits": []
  },
  "aggregations": {
    "type_count": {
      "value": 16
    }
  }
}
```

Precompute Hashes?

Client or `mapper-murmur3` plugin

It Depends

👍 large / high-cardinality fields

👎 low cardinality / numeric fields

Improvement: LogLog-β

https://github.com/elastic/elasticsearch/pull/22323

elastic

Improvement?

"New cardinality estimation algorithms for HyperLogLog sketches"

https://arxiv.org/abs/1702.01284

Inverse Document Frequency

elastic

```
GET starwars/_search
{
  "query": {
    "match": {
      "word": "Luke"
    }
  }
}
```

```
...
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "0vVdy2IBkmPuaFRg659y",
  "_score": 3.2049506,
  "_routing": "1",
  "_source": {
    "word": "Luke"
  }
},
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "2PVdy2IBkmPuaFRg659y",
  "_score": 3.2049506,
  "_routing": "7",
  "_source": {
    "word": "Luke"
  }
},
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "0_Vdy2IBkmPuaFRg659y",
  "_score": 3.1994843,
  "_routing": "2",
  "_source": {
    "word": "Luke"
  }
},
...
```

Term Frequency / Inverse Document Frequency (TF/IDF)

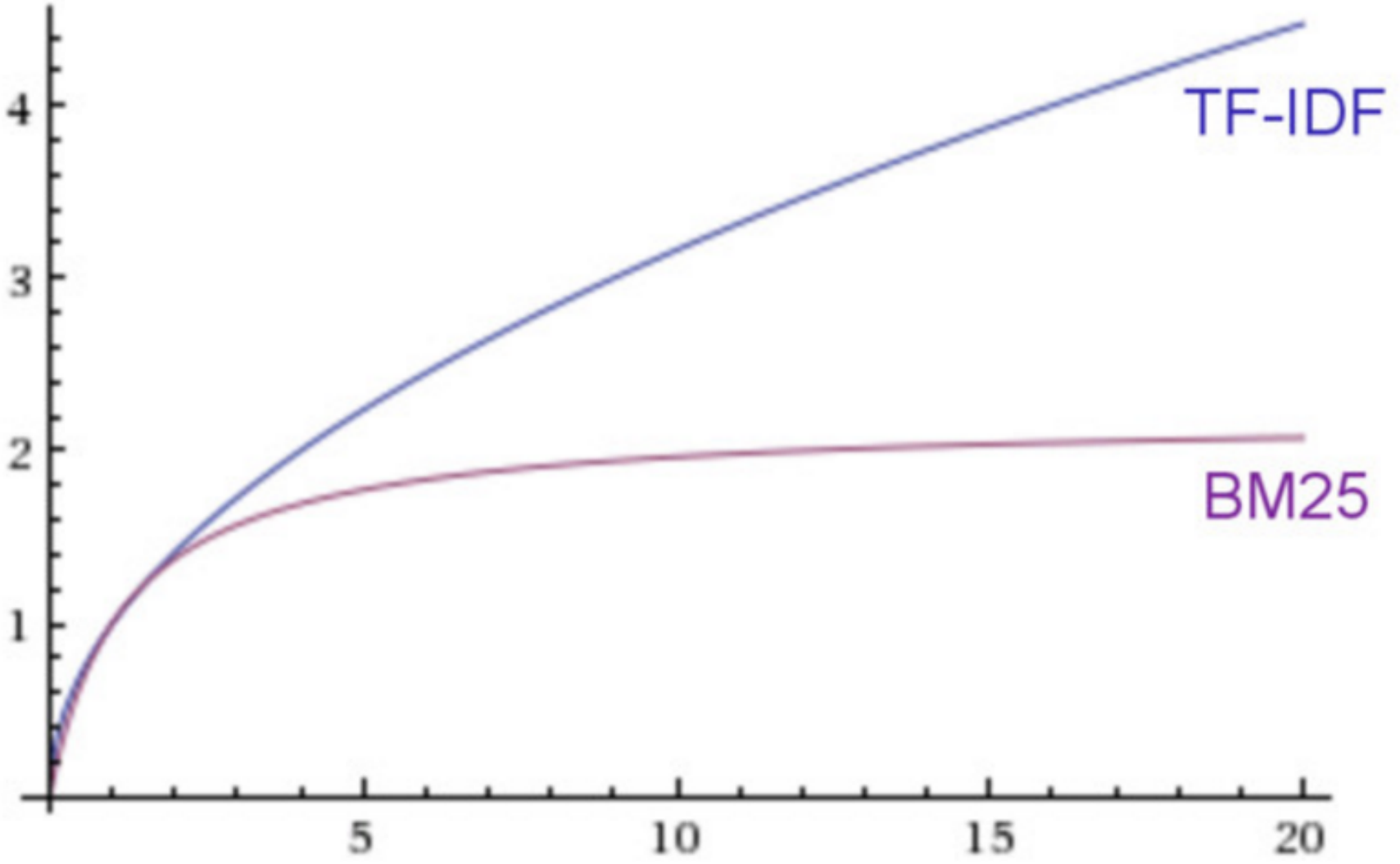
BM25

Default in Elasticsearch 5.0

elastic

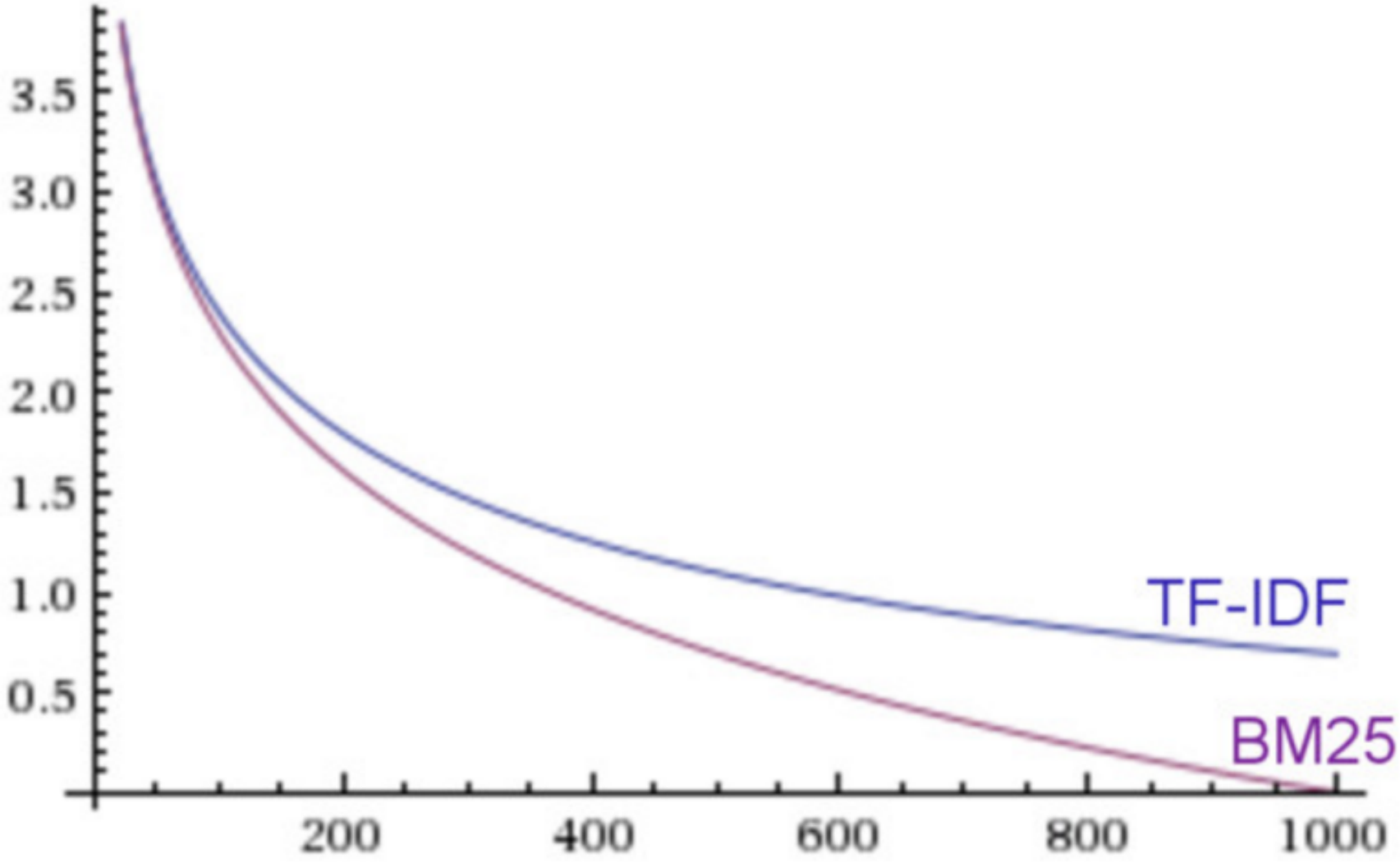
Term Frequency

$$tf(t\ in\ d) = \sqrt{frequency}$$


4
3
2
1
5
10
15
20
TF-IDF
BM25

Inverse Document Frequency

$$idf(t) = 1 + log(\frac{numDocs}{docFreq + 1})$$


3.5
3.0
2.5
2.0
1.5
1.0
0.5
200
400
600
800
1000
TF-IDF
BM25

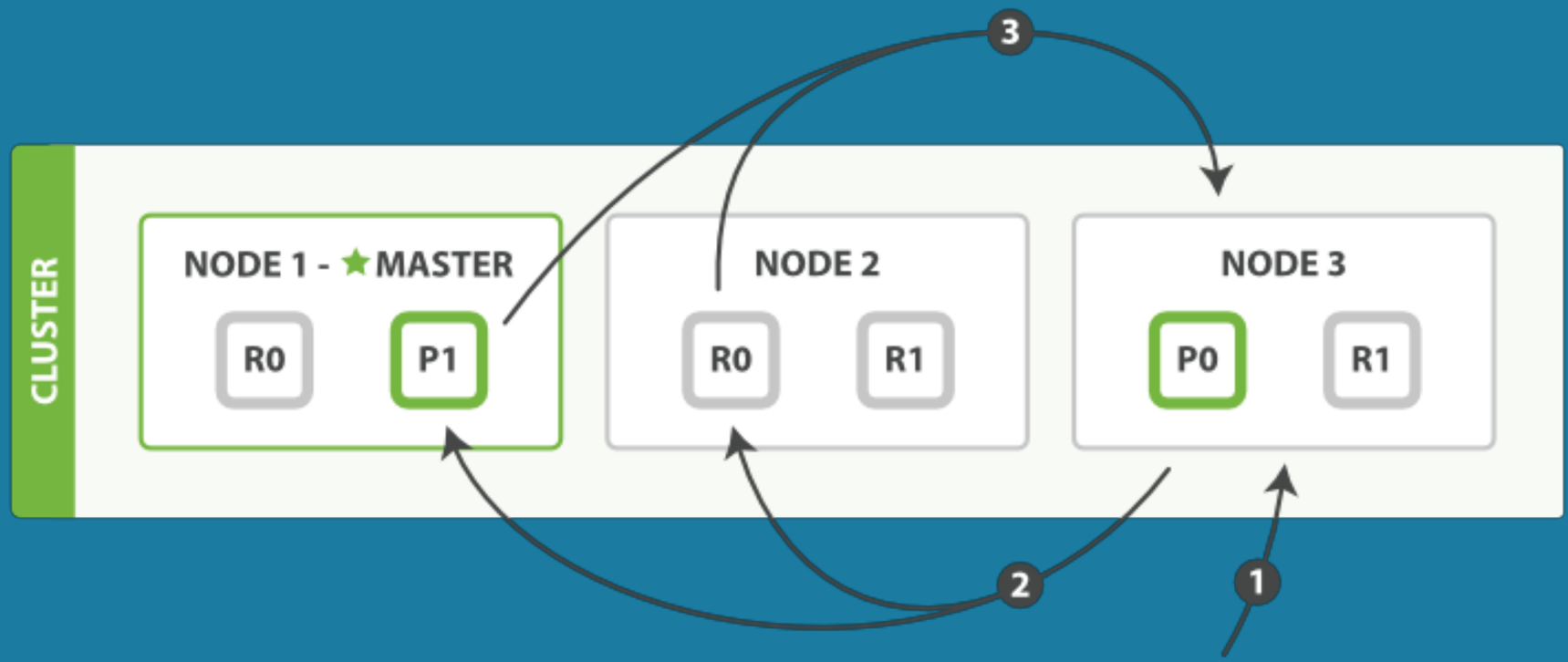
Field-Length Norm

$$norm(d) = \frac{1}{\sqrt{numTerms}}$$

elastic

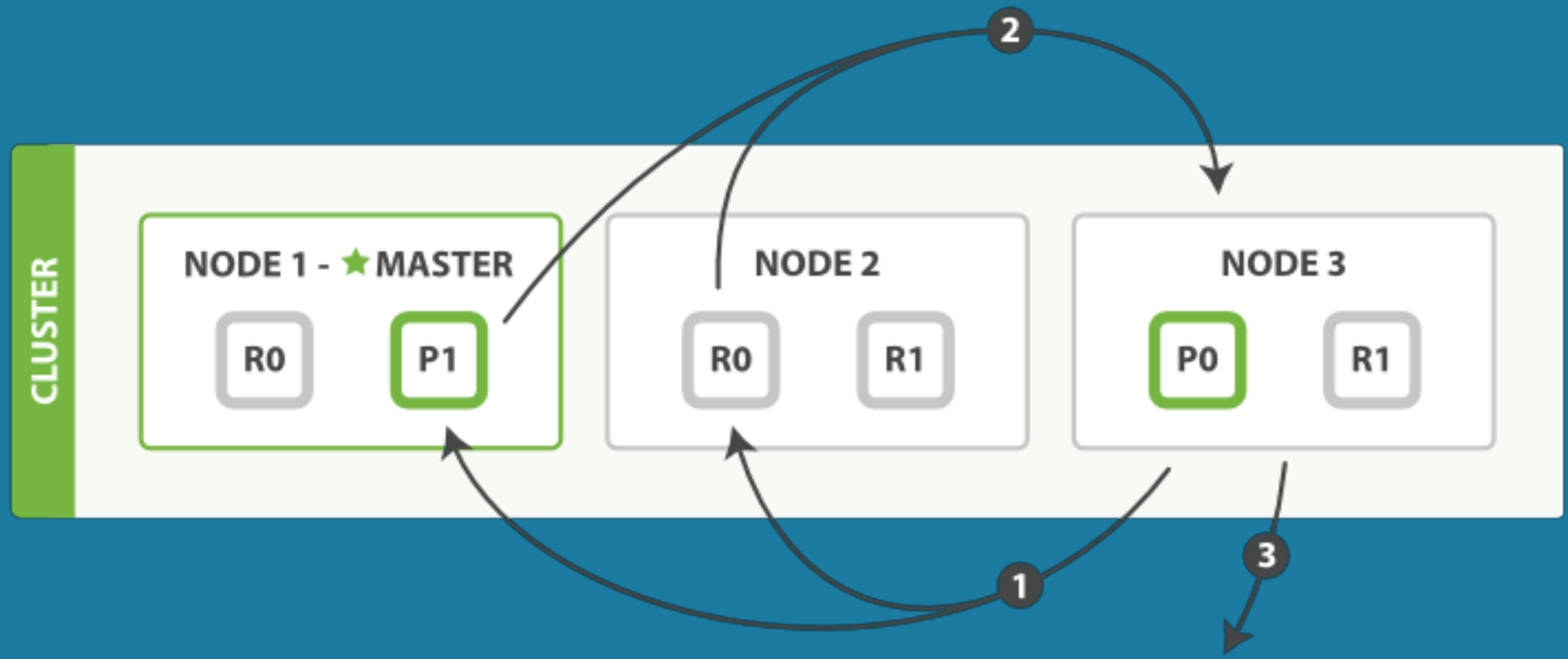
Query Then Fetch

Query



elastic

Fetch



elastic

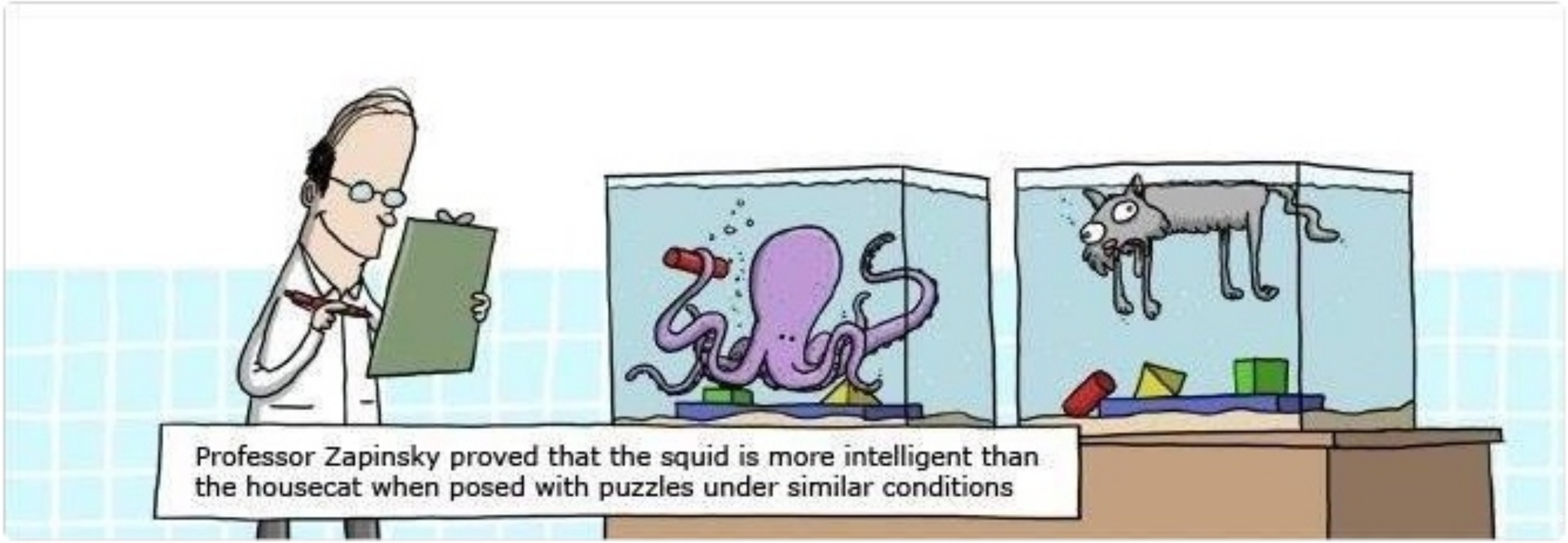
DFS Query Then Fetch

Distributed Frequency Search

elastic

```
GET starwars/_search?search_type=dfs_query_then_fetch
{
  "query": {
    "match": {
      "word": "Luke"
    }
  }
}
```

```
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "0fVdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0",
  "_source": {
    "word": "Luke"
  }
},
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "2_Vdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0",
  "_source": {
    "word": "Luke"
  }
},
{
  "_index": "starwars",
  "_type": "_doc",
  "_id": "3PVdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0",
  "_source": {
    "word": "Luke"
  }
},
...
```


Professor Zapinsky proved that the squid is more intelligent than the housecat when posed with puzzles under similar conditions

Don't use
`dfs_query_then_fetch`
in production. It really isn't required.

— https://www.elastic.co/guide/en/elasticsearch/guide/current/relevance-is-broken.html

Single Shard

Default in 7.0

elastic

Simon Says

Use a single shard until it blows up

elastic

```
PUT starwars/_settings
{
  "settings": {
    "index.blocks.write": true
  }
}
```

```
POST starwars/_shrink/starletwars?copy_settings=true
{
  "settings": {
    "number_of_shards": 1,
    "number_of_replicas": 0
  }
}
```

```
GET starletwars/_search
{
  "query": {
    "match": {
      "word": "Luke"
    }
  },
  "_source": false
}
```

```
{
  "_index": "starletwars",
  "_type": "_doc",
  "_id": "0fVdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0"
},
{
  "_index": "starletwars",
  "_type": "_doc",
  "_id": "2_Vdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0"
},
{
  "_index": "starletwars",
  "_type": "_doc",
  "_id": "3PVdy2IBkmPuaFRg659y",
  "_score": 1.5367417,
  "_routing": "0"
},
```

```
GET starletwars/_search
{
  "aggs": {
    "most_common": {
      "terms": {
        "field": "word.keyword",
        "size": 1
      }
    }
  },
  "size": 0
}
```

```
{
  "took": 1,
  "timed_out": false,
  "_shards": {
    "total": 1,
    "successful": 1,
    "skipped": 0,
    "failed": 0
  },
  "hits": {
    "total": 288,
    "max_score": 0,
    "hits": []
  },
  "aggregations": {
    "most_common": {
      "doc_count_error_upper_bound": 0,
      "sum_other_doc_count": 224,
      "buckets": [
        {
          "key": "Luke",
          "doc_count": 64
        }
      ]
    }
  }
}
```

Change for the Cardinality Count?

elastic

Conclusion

Tradeoffs...

Consistent Available

Partition Tolerant

Fast Accurate Big

elastic

Questions?

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PS: Stickers